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THESIS

Marine Atmospheric Boundary Layer

and Inversion Forecast Model

by

DAVID ALMY BROWER

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Thesis Advisor: K. L. DAVIDSON

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prediction code are under consideration for inclusion in Tactical
Environmental Support System (TESS).

Marine Atmospheric Boundary Layer and Inversion

Forecast Model

by

David Almy Brower

Lieutenant, United States Navy

B.S., United States Naval Academy, 1974

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A computer code for prediction of the marine atmospheric boundary layer is developed. The code is used to predict changes of the capping inversion height, the strength of the specific humidity and potential temperature 'jumps'at the inversion, the well-mixed relative humidity in the layer and the lifting condensation level for possible cloud/fog formation. The code is based on recently formulated integrated models for the clear or cloudy marine planetary boundary layer capped by an inversion. The initialization is based on radiosonde data and, as such, the code was developed to be used with the Integrated Refractive Effects Prediction System (IREPS) assessment code. It has been extended to be used with any single platform having atmospheric sensing capabilities, radiosonde or dropsonde. IREPS and hence the MABL prediction code are under consideration for inclusion in Tactical Environmental Support System (TESS).

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I. INTRODUCTION

Modern warfare has become critically dependent on the entire electromagnetic spectrum for command and control communications, for weapons guidance, for electronic warfare support and for countermeasures. Tactically essential systems are highly affected by the environment even when conditions are not severe in the historical sense. Enhancement or degradation of the operational performances of EM/EO systems has become a primary concern of task force commanders. As such, the deployment of resources and the modification of tactics based upon environmental factors in EM/EO propagation will, to a very large extent, determine the effectiveness of sensor, weapon and communications systems.

Environmental effects on EO/EM system performance can be grouped in the general categories of refraction (EM), wave front distortion (EO), extinction (EO), and dispersion (EM/EO). Environmental factors contributing to these effects are the vertical gradients of pressure, temperature and humidity for refraction, small scale inhomogenities (turbulence) of the index of refraction for wave front distortion, concentration of water vapor and size distributions of aerosols for extinction and turbulent transport for dispersion. All of these factors are multi-variable in terms of their dependence on the routinely

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measured and predicted meteorological variables: pressure, wind, temperature and moisture. The gradient of the index of refraction is the only factor for which the required accuracy exists for direct description by existing or forseen measurement capabilities. Turbulence and aerosol descriptions will have to be obtained by indirect methods due to measurement complexities which preclude measurement on operational ships.

There are requirements to describe all of these factors for the atmospheric region extending from the surface to 0.5-1.5 km above the surface, spanning the Marine Atmospheric Boundary Layer (MABL). The MABL is cooler and more moist than the overlying air and is capped by a layer (inversion), 50-100 meters thick, in which temperature increases and humidity decreases with height. Critical values of the index of refraction gradients leading to anamalous EM propagation can be present within the shallow capping inversion because of the humidity and temperature gradients. The entire affected region (duct) extends below the inversion, and determining its lower boundary is essential. High turbulence can be present in the inversion as well as in the surface layer and this can cause degradation of slant path optical propagation. Turbulence intensities in the inversion are usually one to two orders of magnitude greater than they are immediately below,and are two to three orders of magnitude smaller immediately above

the inversion. Tactically significant degradation of infrared energy is due to water vapor absorption and to scattering by marine aerosols, and is thus usually restricted to moist MABL.

All of the above features depend critically on local detailed vertical structure of the atmosphere. Therefore regional climatologies are not useful for operational predictions, because the significant vertical structures are lost in averaging, and also because most historical measurements do not relate to specific EM/EO requirements. Furthermore, the gradients, and hence, the affected regions cannot be explained on the basis of large scale atmospheric flows since the nature of the gradients are due to dynamic processes which are controlled by near surface as well as by larger scale features.

We believe a ´gap´ has existed in past efforts to characterize the tactical environmental conditions. The gap is between two extreme approaches of relating conditions to 1) near surface observations, and 2) to larger scale predicted synoptic patterns. Clearly, to assess the above features, local measurements are desirable. Measurements (radiosondes) are made infrequently and, as time progresses, the initial point measurement becomes less applicable and a predictive scheme is needed. One must consider a transition to climatology, large scale numerical analyses and predictions, or dynamic models based on the initial

soundings which are available at the operational location. Climatology has already been addressed and discounted. Ruggles (1975) has examined the capabilities of large scale numerical procedures at remote facilities and has argued convincingly that they are not sufficient.

Needed are characterizations of coupled local oceanic and atmospheric mixed layer features for time scales from 12 to 18 hours and for spatial scales from 50 to 300 km. Significant cnanges occur in both mixed layers over these temporal and spatial scales. Predicting these changes is now possible using available measurements and reasonable physical models which have recently been formulated.

This paper will describe results from observational and model evaluation/formulation efforts with these models which provide evidence that tactically relevant forecasts can be made over the required scales. The MABL is emphasized in this discussion but, as will be seen, the MABL model must eventually be coupled with an Ocean Boundary Layer (OBL) model to adequately describe the system. This is the object of separate investigation by the author and faculty at NPS.

The long term objective of work in these areas is to make reliable 6-18 hour forecasts of properties within the MABL and OBL. The near term objectives are 1) to verify and reformulate existing models for the responsible physical processes and 2) to develop measurement procedures which are suitable for routine observations from a single ship or

aircraft.   For the finalized model it will be necessary to predict such properties as the height of the inversion, the strength of the gradients and fluxes at the inversion and at the surface, and the values of well mixed parameters in the region between the surface and the inversion.
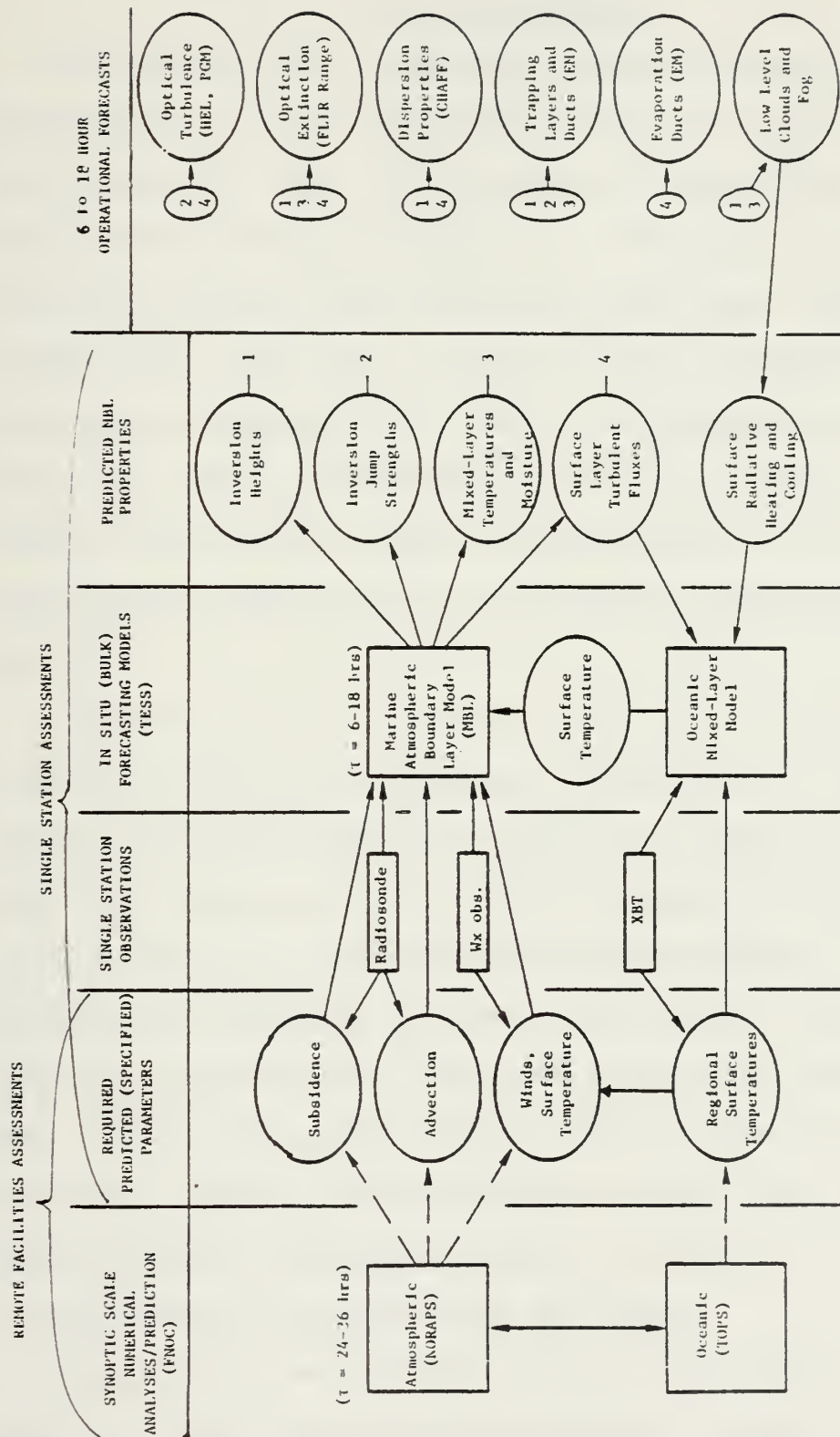
Fig. 1.

Illustration of input parameters, predicted properties and operational forecasts associated with a bulk atmospheric boundary-layer model (MABL). Numbers to the left of operational forecast items pertain to the required predicted MABL properties. The bulk atmosphere and ocean mixed-layer models would be coupled in a shipboard, aircraft micro-computer. Dashed lines (— —) coming from remote facilities imply that the required information could be obtained from these, but the in situ capabilities should be possible without the sources.

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II. BACKGROUND

This section will provide a general outline of the environmental descriptions required and the models which can used to predict them. The possible input parameters and models are delineated in Figure 1. Tactical forecasts to which the improved understandings would apply appear on the extreme right hand side. Single station assessment constraints associated with the local atmospheric and ocean models are timely and compatible with the concept of the Tactical Environment Support System (TESS) as recently described by NEPRF scientific personnel (NEPRF METRO Report, July 1981).

As stated, we will consider only the local atmospheric mixed layer model and associated descriptions. The local oceanic predictions would be made by an oceanic mixed-layer model (e.g. Garwood, 1977) and the regional predictions would be made by a three dimensional atmospheric (e.g. NORAPS) and a regional oceanic (e.g. Tactical Ocean Prediction System-TOPS) numerical prediction model. The ocean mixed layer model and the regional numerical prediction schemes are objectives of other basic and exploratory Navy sponsored research efforts.

A. METEOROLOGICAL DESCRIPTIONS AND MODELS

From a local perspective, let us consider an idealization of the oceanic-atmospheric system. The sea-air

interface is bordered by oceanic and atmospheric turbulent
mixed layers which effectively insulate the bulk ocean and
atmospheric regions. The primary sources of the turbulence
within the layers are the velocity (current) and buoyancy
(density) gradients at the interface. Even under conditions
where the water is slightly cooler than the air, buoyancy
forced velocity fluctuations within the layer can be quite
large and mix the entire MABL from the surface to the
inversion. The large vertical mixing yields constant
(well-mixed) wind, temperature and humidity profiles above
the surface. At the top of the atmospheric mixed layer
there is the inversion, a thin transition region. Examples
of observed well-mixed profiles and the inversion are shown
in Figure 2(a).

The atmospheric mixed layer interacts with the free
atmosphere at this interface by means of turbulence forced
entrainment. Entrainment brings dry, warm air into the
mixed layer and also increases the surface winds if there
are higher winds aloft. Stratus clouds form within the
layer if entrainment causes the moist mixed layer to extend
above the lifting condensation level.
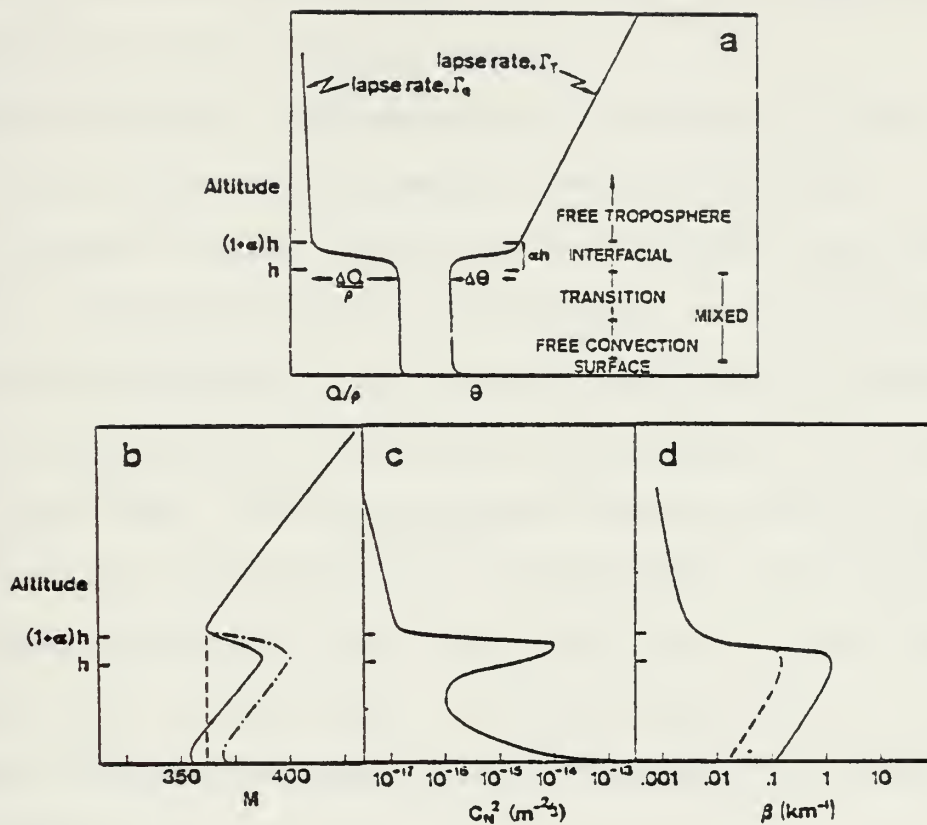
Fig. 2. Simplified meteorological and tactical features of the MABL and
overlying region including (a) humidity mixing ratio, Q/ρ, and
potential temperature, θ, profiles and subregions, (b) modified
index of refraction, M, profiles, (c) optical turbulence inten-
sity, C_N^2, profiles, (d) total extinction coefficient, β
(absorption and scattering), profile.

Over a time scale of 24-36 hours, physical processes within the mixed layer are also controlled by the large scale, non-stationary, synoptic flows. Synoptic scale mean vertical motion and advection will have to be prescribed or predicted over the forecast period.

The previously inferred well-mixed nature of the convective MABL has implications for the vertical distributions of mean values and the vertical flux scales of wind-U^*, temperature-T^* and humidity-Q^*. One implication already illustrated is that properties which are conserved during mixing can be treated as being constant with height within the MABL. These parameters are the specific humidity and potential temperature for a clear MABL and equivalent potential temperature and total (vapor plus liquid) specific humidity for a cloudy MABL. A second implication is that vertical fluxes of the well-mixed parameters vary linearly with height.

These implications enable predictions of MABL evolution to be based solely on fluxes at the upper (inversion) and lower (surface) boundaries and the large scale subsidence and advection. They form the basis of recent model formulations by Deardorff (1976) and Stage and Businger (1981). Fluxes at both boundaries are due to buoyant and mechanically generated turbulence for the clear case. The linear height variations of the fluxes allows buoyant fluxes at the inversion to be more readily estimated on the basis

of general cloud features. Methods exist for estimating synoptic scale forcing from single station measurements but further efforts are required to achieve the accuracies required in MABL predictions.

In general, existing models are quite good for the clear sky MABL and fair to good for the cloudy MABL. Considerable effort is now being directed to improving the models for the cloudy MABL. The existence of cloud layers in the MABL is very sensitive to both the sea surface temperature and the entrainment rate and, in turn, clouds have a profound effect on the short and long wave radiation budget at the surface. Fairall et al (1981) provide a discussion on the approach and the status of abilities to predict the evolution of the MABL.

B. TACTICAL DESCRIPTIONS

Figures 2b-d illustrate tactical descriptions discussed in the Introduction (appearing in the right hand column of Figure1). Meteorological processes and features relevant to these tactical descriptions are those that were discussed above (Figure 2a and column 4 of Figure 1). Several meteorological factors affect each tactical description as indicated by the numbers, 1-4, in Figure 1. A few of the significant properties and values in the tactical descriptions are described in the following paragrapns.

The M profile in Figure 2b describes the refracted EM ray radius of curvature, relative to the earth's radius of curvature. If M decreases with height, a trapping layer is formed because the EM ray will bend downward relative to the earth. This causes the formation of a duct. The upper boundary of the duct is at the M minimum; the lower boundary is at the height where this same value of M occurs below the trapping layer, as shown in Figure 2b. The M profile is determined by pressure, temperature and humidity profiles, so values of well mixed temperature and humidity determine the lower boundary of the duct. A decrease of mixed layer M value with time could cause a surface based duct to become an elavated duct as shown in Figure 2b. This could occur if the mixed layer became warmer and drier due to entrainment of overlying air. Warming and drying of the mixed layer by entrainment would also increase the height of the evaporation duct, a ducting layer immediately adjacent to the surface. Examples of extended ranges and holes occurring with a duct appear in Figure 3 (Hitney, 1979).

The Cn2 profile in Figure 2c shows the vertical variation of turbulence which would affect optical wave front distortion. We see that Cn2 is largest near the surface and in the inversion. Values in these regions are 1-2 orders of magnitude larger than those in the mixed layer and above the inversion. Cn2 values near $10(-14)$ m $-2/3$ are representative for these two regions. The importance of

this value is illustrated in Figure 4 with a simulated image

of a remotely piloted vehicle as viewed through Cn2 regions

of 0 (no turbulence), 10(-15), and 10(-14) m -2/3 (Kearns

and Walter, 1978).

The extinction coefficient, B, profile is shown in

Figure 2d. B is inversely proportional to the range of IR

systems and primarily depends on the absolute humidity and

the aerosol size distribution. Aerosol size distributions

depend on the generation rate of sea salt particles and on

the relative humidity as determined by both the moisture and

temperature. Therefore, IR extinction is very dependent on

the entrainment of relatively clean, dry and warm air from

above the inversion and on the surface wind generation of

the sea salt particles (Davidson et al, 1982). As

illustrated, the extinction coefficient is large within the

mixed layer and increases with relative humidity which

increases with height. The increase of extinction with

height is important in slant path range considerations.
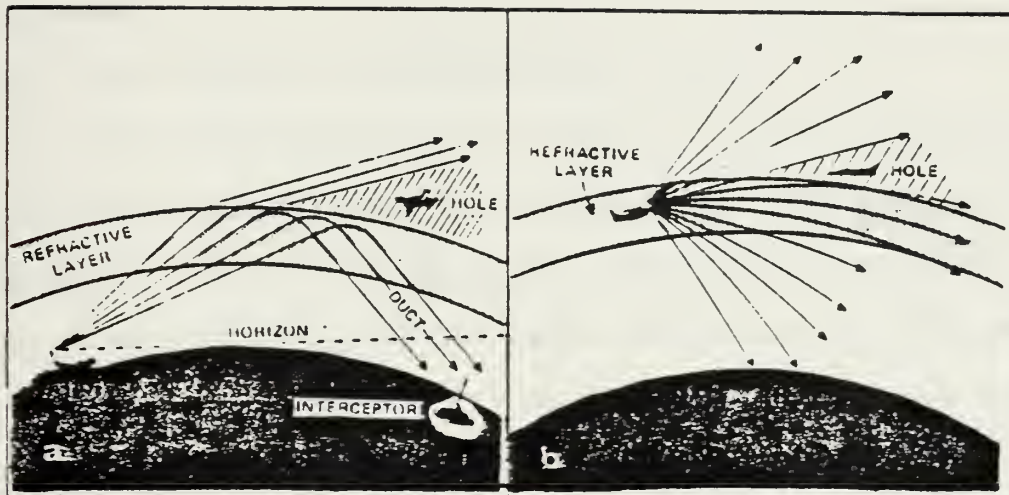
Fig. 3. Examples of extended ranges and holes for EM ducts for (a) surface-based duct and a shipboard air-search radar and (b) elevated duct and an airborne early-warning radar (from Hitney, 1979).

Fig. 4. Computer simulated image remotely piloted vehicle (RPV) as viewed with 8-12 m IR sensor (range 2 km, visibility 15 km, threshold 4.5 nW) through atmosphere with C_N^2 values of (a) 0 (no turbulence), (b) 3.7 x 10^{-15} m$^{-2/3}$ and (c) 1.0 x 10^{-14} m$^{-2/3}$ (from Kearns and Walter, 1978).

III. <u>MABL OBSERVATIONS AND PREDICTIONS</u>

A recently obtained data set will be used to demonstrate the prediction of changes in the MABL. The demonstration will show:

   a) the status of available data sets,

   b) that the assessment of relative roles of dynamic processes in the MABL can be based on a relatively simple physical model which includes specifiable inputs,

   c) that, at the present time, we only have limited evidence that changes can be predicted. The rigorous specification or description will require further interpretive efforts and, perhaps, improved formulation of the separate models.

A. MABL OBSERVATIONS

The data were obtained during the Cooperative Experiment on West Coast Oceanography and Meteorology (CEWCOM-78) conducted west of San Nicolas Island, CA during May of 1978. Observations of the oceanic and atmospheric mixed layers were made from the R/V ACANIA; radiosonde observations were also made at surrounding shore stations. The data to be shown are from a 48-hour period, 5/19/1200 to 5/21/1200 PST. The R/V ACANIA was cruising slowly (2-3 knots) into the wind and returned to an initial point approximately every 12 hours. The general location of the R/V ACANIA during the 5/19 to 5/22 periods and locations of surrounding snoreline

radiosonde sites appear in Figure 5.

The period was one of steady onshore flow caused by the combined effects of intensification of the Eastern Pacific High and the persistence of the Mexican thermal low. The only apparent change in synoptic scale forcing was an increase in the offshore pressure gradient. Advection in the atmosphere was moderate. However, MABL evolutions were primarily determined by subsidence, surface fluxes, and entrainment at the inversion. Satellite imagery showed uniformly increasing stratus coverage (thin to heavy) during the period with a cellular (broken) coverage occurring late on the 21st.

Acoustic sounder returns, mean surface layer parameters, and sea surface temperature during the 19-21 May period were all measured from the R/V ACANIA and are snown in Figures 6b-d. Composite potential temperature profiles from shipboard and shore station radiosonde and temperature profiles from ship deployed XBT's appear in Figures 6a and 6e, respectively. Although these descriptions of MABL and OBL changes were obtained from an instrumented research vessel, all can be obtained from operational ships. This includes the acoustic sounder record.
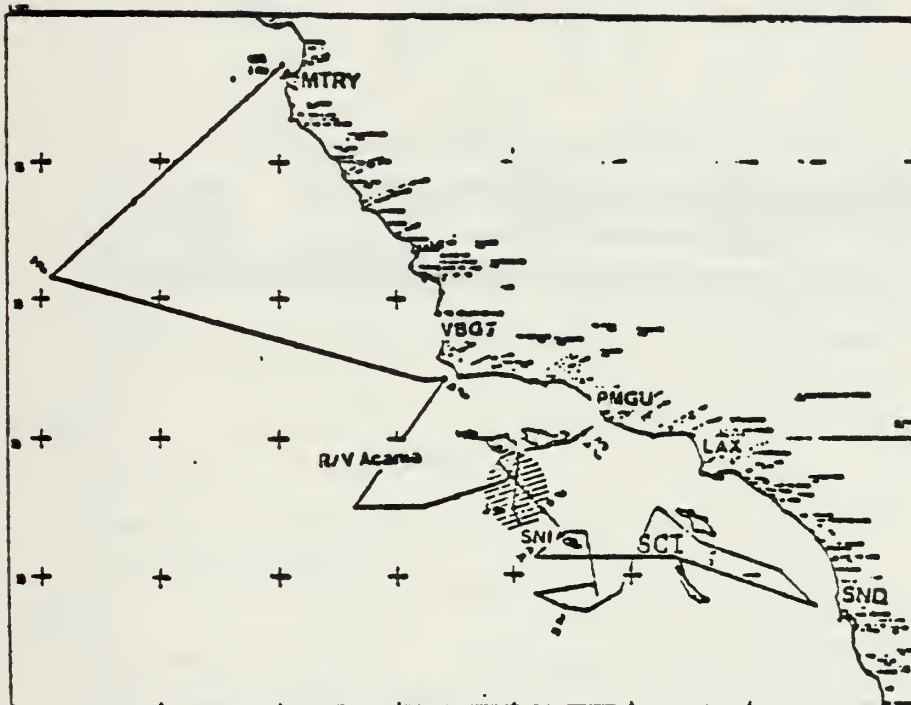
Fig. 5

Tract of R/V Acania and location of shoreline radiosonde sites during
CEWCOM-78. General location of R/V Acania during 19-21 May period is
indicated by hatched area N-NW of San Nicolas Island (SNI).
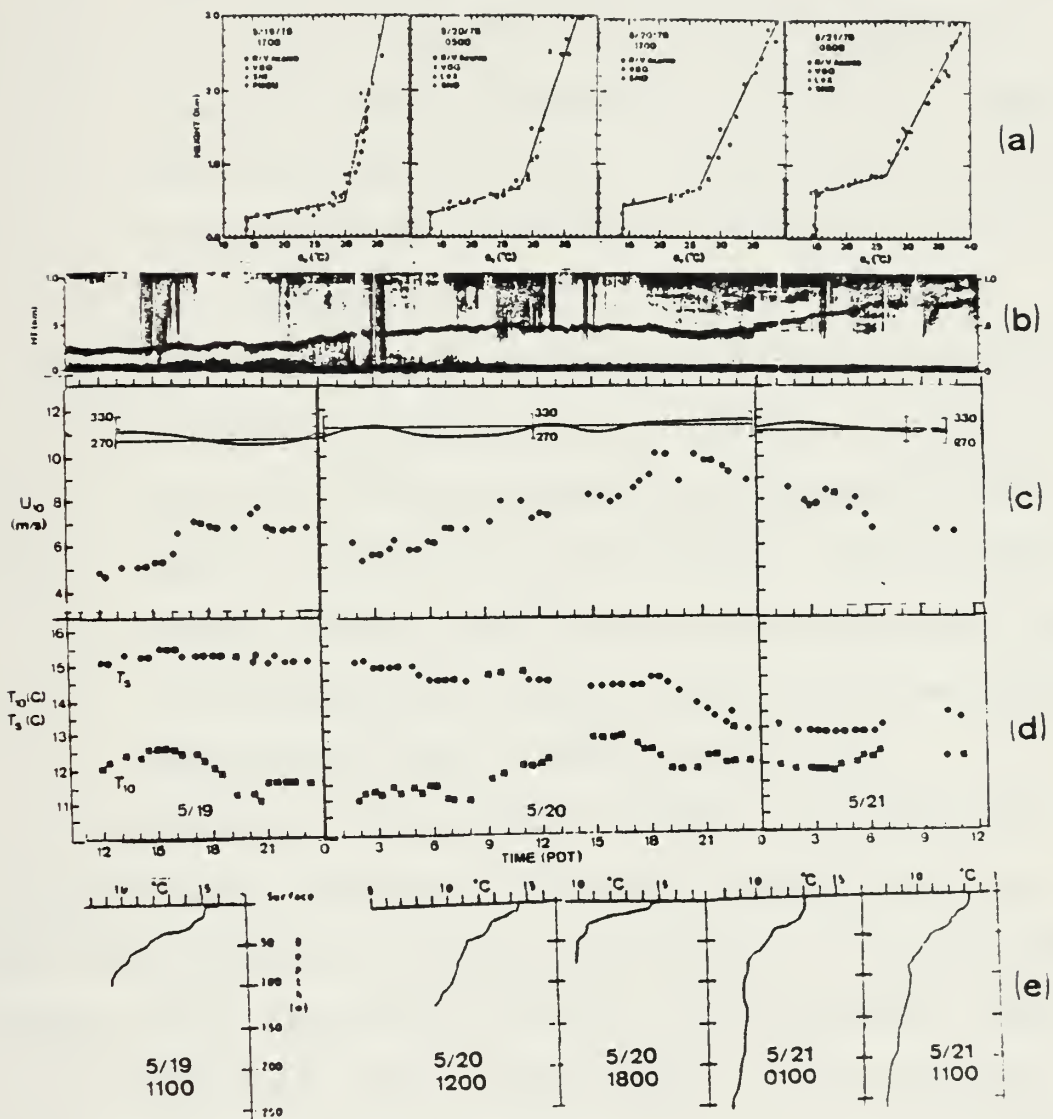
Fig. 6

Atmsopheric and oceanic mixed-layer observations, during CEWCOM-78
(a) potential temperature composite profiles, (b) acoustic sounder
record, (c) 10 meter wind speed, (d) 10 meter and surface temperature
and (e) XBT traces. All data except indicated profiles in (a) were
obtained from R/V Acania.

Changes of atmospheric features which would have been tactically significant in view of the time scale and their magnitudes were:

a)   The MABL depth increased from 250 m to 750 m over the 48 hour period. The changes occurred over relatively short intervals, from 20/00 to 20/04, and from 21/00 to 21/08. The MABL depth remained nearly constant during the intervening 12 to 18 hour periods.

b)   The surface layer temperature increase from 20/00 to 20/15 is indicative of entrainment of overlying warm air. The entrainment was presumably also a factor in the wind speed increase over the same period, which caused the warm shallow ocean layer to be deepened by mixing, lowering the sea surface temperature after 20/1800 (Figure 6d).

In conjunction with changes in MABL structures and parameter values depicted in Figure 6, changes occurred which are important to operational systems. Some of these changes can be determined directly from parameters measured in this scientific observational effort. M profile and cloud base heights and condensation levels can be calculated from the measured composite humidity and temperature profiles. Surface layer extinction coefficients have to be determined from the measured humidity and aerosol size distributions. The method for determining extinction

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coefficients from aerosol data has been described by
Schacher et al (1981). Surface layer Cn2 values and
evaporation duct heignt can be determined with considerable
certainty from measured surface layer wind, temperature,
humidity and surface temperature values using expressions
described by Davidson et al (1981) and Fairall et al (1978).
Extinction and Cn2 profiles have to be based on more recent
and, hence, less substantiated expressions such as those by
Wells et al (1977) and Wyngaard and Lemone (1980).

Results from these determinations appear in Figures 7
and 8 along with the composite potential temperature, O, and
water vapor mixing ratio, q, profiles (Figure 7a) and the
inversion height (Figure 8a). The observed results indicate
that for the observation period:

a) The EM duct associated with the inversion gradients
   evolved from being surface based to being elevated
   (Figure 7b) and the evaporation duct height ranged
   from below 5 m to above 8 m (Figure 8b),

b) Optical turbulence, Cn2, in the surface layer
   varied from 10(-15) to 10(-14) m -2/3 over the
   period (Figure 8c) and values in the inversion
   increased from 10(-16) to 10(-15) m -2/3 (Figure
   8c),

c) Surface layer aerosol extinction in the 8-12 um IR
   region increased during the first 6 nours (5/19
   1200-1800) because the relative numidity increased.

It decreased during the last 18 hours (5/20/1800 to
5/21/1200) because of relative humidity and wind
decreases (Figure 8d),

d) Stratus clouds persisted through the period. The
base lifted from about 100 m at 5/19/1800 to 600 m
at 5/21/1200. This is evident in the extinction
profile (Figure 7d).
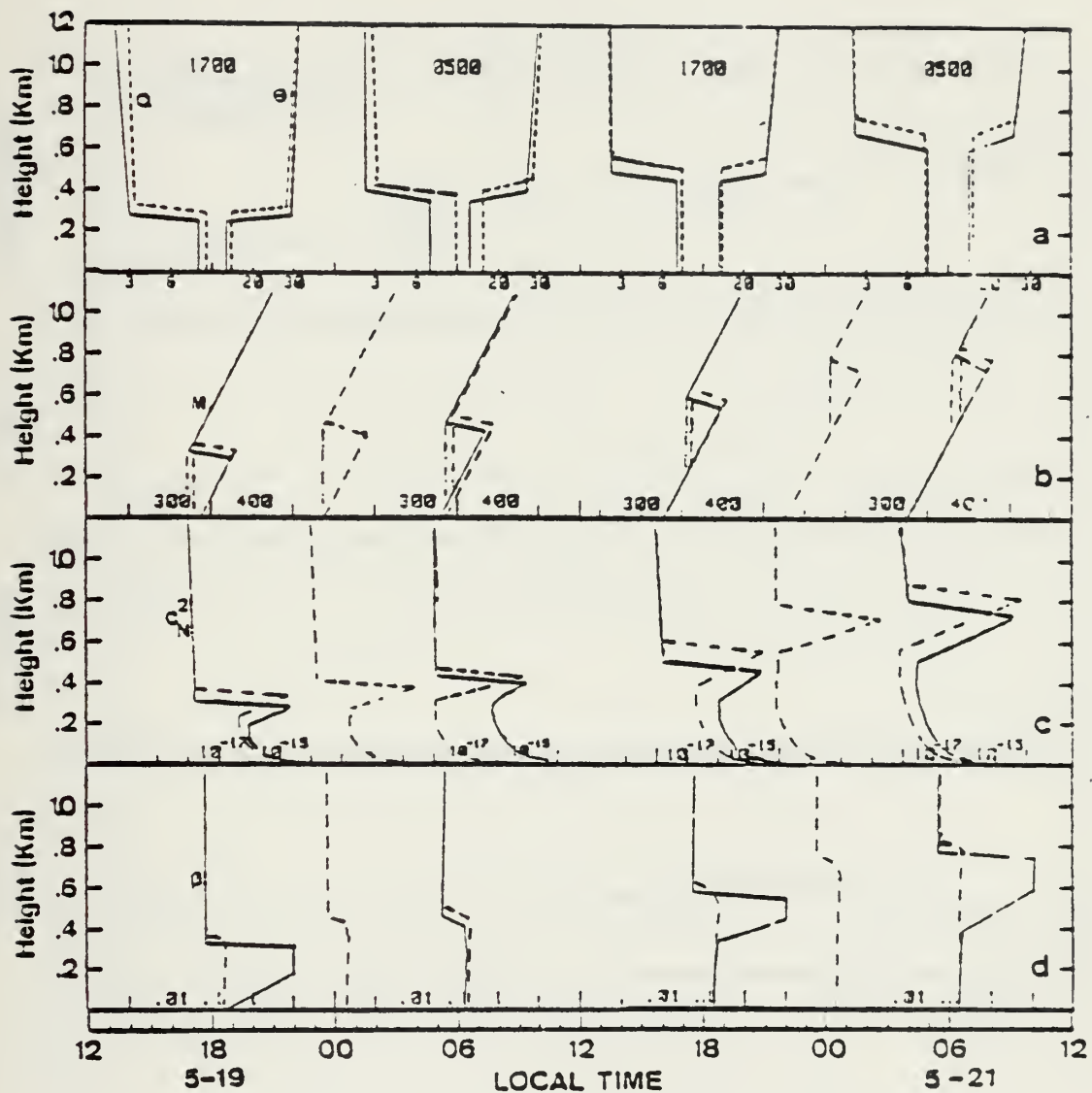
Fig. 7

Observed/computed and predicted MABL profiles for 5/19/1200 to
5/21/1200 CEWCOM-78 period including (a) Q (g m^{-3}) and θ(°C),
(b) M, (c) C_N^2 (m$^{-2/3}$) and (d) total extinction coefficient, β
(km^{-1}). Solid lines correspond to observed and dashed to model
prediction.
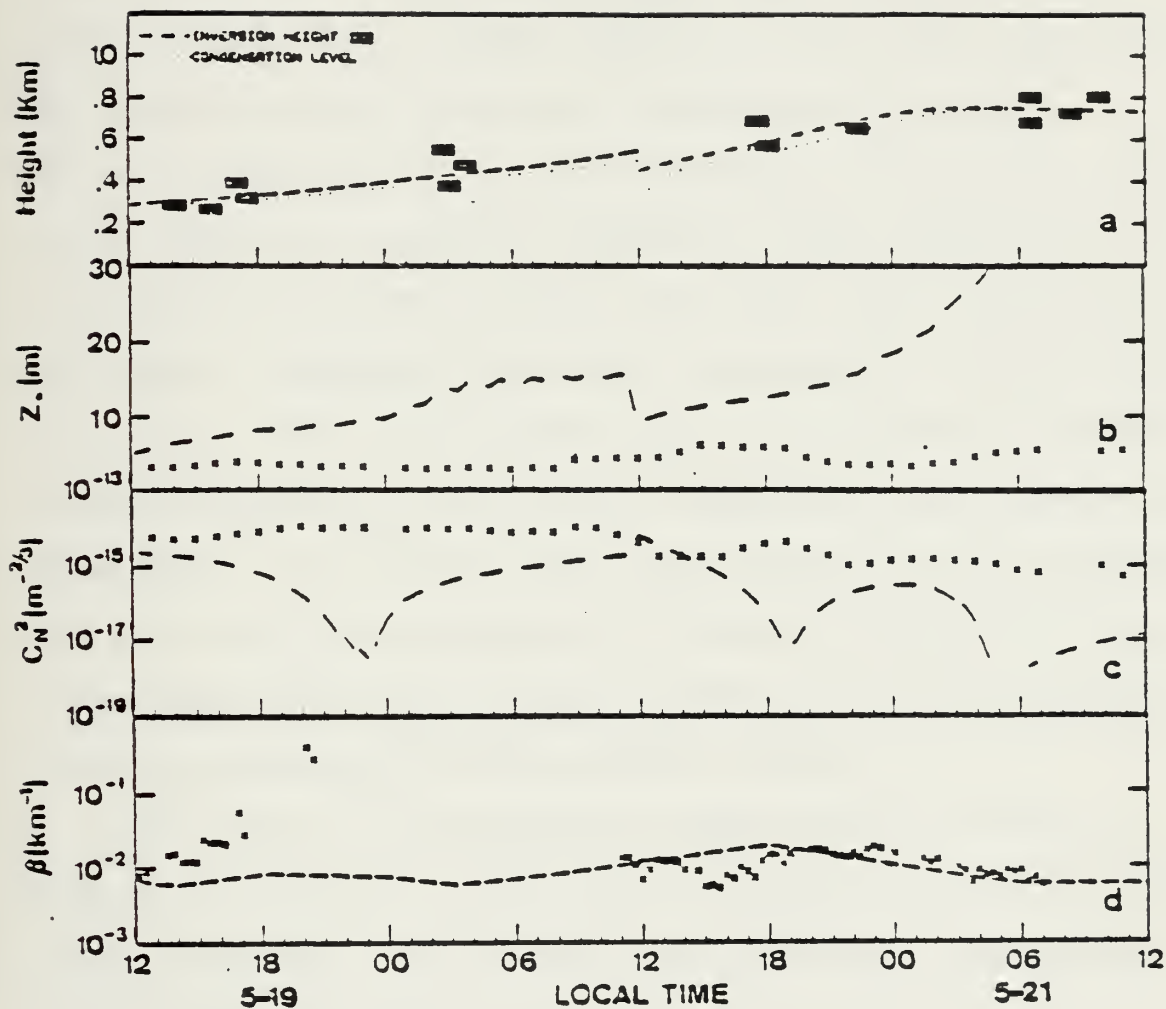
Fig. 8

Observed/computed and predicted surface layer values for
5/19/1200 to 5/21/1200 CEWCOM-78 period including (a) inversion
height and lifting condensation level, (b) evaporation duct,
(c) C_N^2 $m^{-2/3}$ and (d) aerosol scattering extinction coefficient,
β. X's are observed and dashed lines are model predictions.

B. MODEL PREDICTIONS

During the past five years, investigations were
performed on surface layer and mixed-layer scaling of small
scale turbulence and aerosol properties (Davidson et al,
1978; Fairall et al, 1980; Schacher et al, 1981a and 1981b).
The investigations led to the application of a time
dependent MABL models based on entrainment energetics and on
cloud radiative transfers suggested by both Deardorff (1976)
and Stage and Businger (1981). The model requires as input
an initial atmospheric sounding (radiosonde), the mean winds
at a level within the surface layer (10-30 meters) and the
surface temperature. Well-mixed temperature and humidity are
predicted so the surface wind and wind shear at an inversion
are the only local atmospheric variables which have to be
prescribed. The larger scale subsidence and advection must
also be prescribed for the forecast period.

The steps in the prediction computation are shown in
Figure 9, where it is noted that procedures are the same for
clear and cloudy cases except for entrainment computation
and estimating cloud top cooling. Fairall et al (1981)
include comprehensive discussions of how applicable physical
processes are teated in the model and how available data can
be used to estimate the processes. Because of the
simplified physical model, the computations do not require
numerical integration on a vertical grid so the computer
storage requirements can be satisfied by available shipboard

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microcomputers. In fact, the use of a hand-held calculator
is being considered for these procedures. Particular
computations of interest are those for the evaporation duct,
the surface flux, flux of total heat and momentum and the
depth change of the mixed layer. Routines for computing and
graphing the M-profile can be system are used on the
HP-41C/V and printer hand-held system.

Predictions of MABL changes were made with the
simplified model for the 48 hour period (5/19/1200 to
5/21/1200) corresponding to observed results in Figure 6a-e.
The predictions were made for two separate 24 hour periods
starting at 19/1200 and at 20/1200. The initial profile for
the 19/1200 starting time was that obtained at San Clemente
Island (SCI in Figure 5) at approximately 1000. Initial
profiles for the 20/1200 starting time were averages of the
composites at 20/0500 and 20/1700. The sea surface
temperatures were those at each start time as shown in
Figure 6d and were 15 and 14.5 C, respectively. The surface
wind observed during the forecast period was specified to
increase linearly from 5 m/sec at 19/1200 to 10 m/sec at
20/2100 and then to decrease linearly to 7 m/sec at 21/1200.

Larger scale synoptic advection, was estimated to be
zero from the thermal wind. Subsidence for the second
period, starting at 20/1200, was adjusted on the basis of
that value required for agreement between predicted and
observed mixed layer depths during the first period. Hence,

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the model was also used to estimate the "most probable"
synoptic scale subsidence. The tuning of the subsidence
value, based on comparisons of the latest sounding and
predictions from a previous sounding, has been described as
"hindcasting".
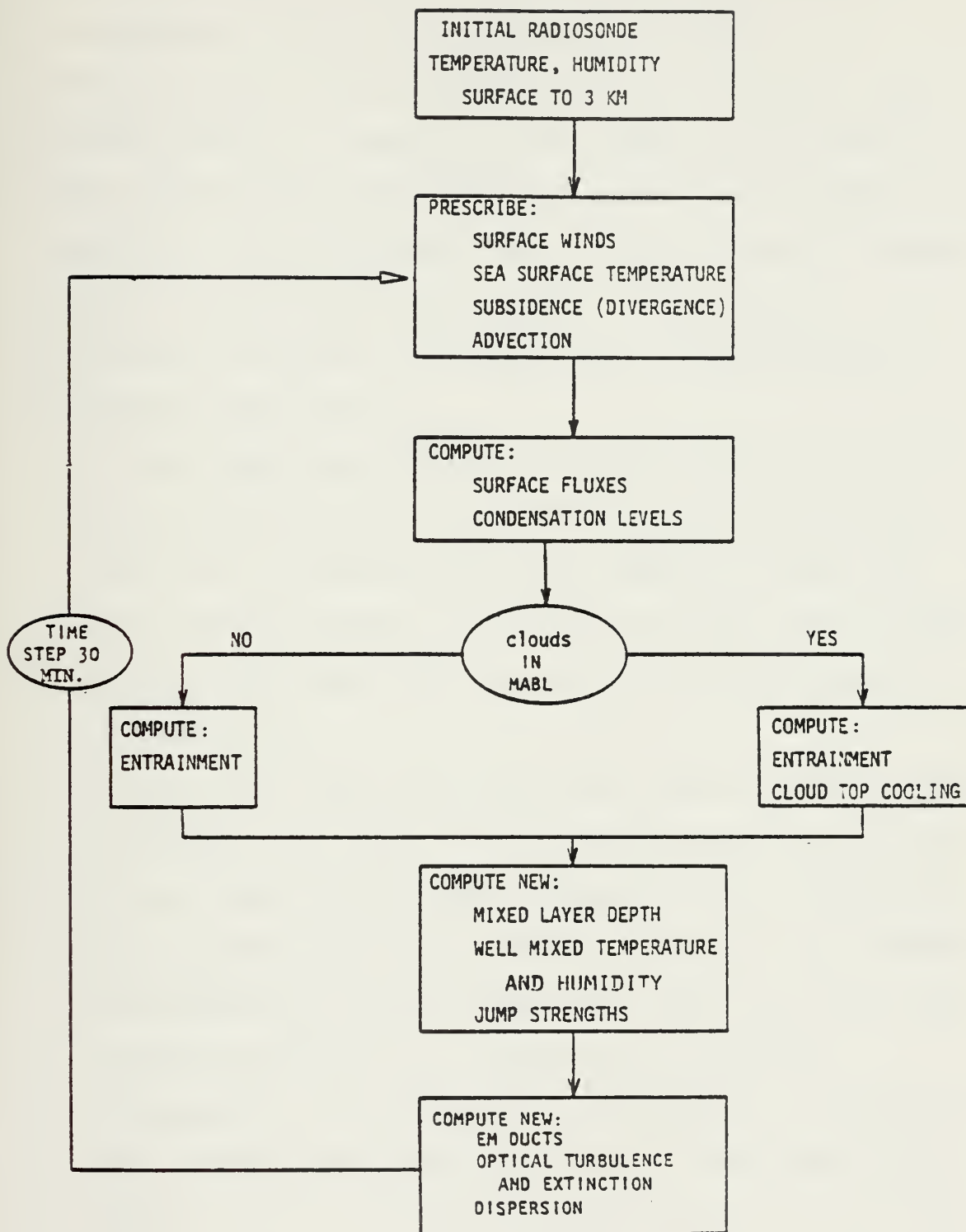
Fig. 9. SCHEMATIC OF INPUT, PRESCRIPTION AND COMPUTING
STEPS IN MABL PREDICTION

The predictions are illustrated in Figures 7 and 8 along with the observed values. These predictions were made using the Deardorff (1976) cloud topped entrainment parameterization and Davidson et al (1978) surface layer parameterization. Results for the same period using the Stage and Businger entrainment parameterization appear in Appendix B. The agreement near 20/1200 in Figure 8 occurs because the model was reinitialized at that point. Significant outcomes from comparisons of observed and predicted results are:

a) The mixed layer depth (inversion height, Figure 8a) was predicted quite well. This increase during the later part of both periods was caused by cloud top entrainment because the predicted surface layer became stable and, hence, there existed no surface buoyancy flux forcing.

b) The cloud cover was accurately predicted to persist throughout the first period and for the first 15 hours of the second period, as indicated by the condensation level being below the inversion in Figure 8a. However, the predicted cloud thickness was less than that which actually occurred. As indicated in preceding discussions, the cloud cover was observed to break up on the 21st and the prediction after 21/0600 agres with that.

c) The well mixed temperature and humidity and the jump predictions (Figure 7a) are reasonable except at 20/0500. The predicted well mixed temperature was too warm by 1-2 C at all other comparison times. This led to the surface layer becoming stable when in actuality it remained unstable throughout both periods (i.e. surface temperature higher than 10 m temperature.) It is believe that the cooling associated with the clouds was not sufficient. It will be seen that the surface layer was too warm and stable during the night hours.

d) The predicted M profiles (Figure 7b) were very accurate in terms of the surface based duct evolving to an elevated duct. It is interesting that even when the predicted well mixed temperature and humidity were much too high (20/0500) the M profile was verified. This occurred because their respective affects on M were compensated.

e) The predicted $Cn2$ profiles (Figure 7c) gave good values for the inversion region and reasonable values for the mixed layer, except for 20/0500. Agreement within a factor of three is considered reasonable for $Cn2$. The inversion region values were based on the convective mixing velocity, W^* (Wyngaard and Lemone, 1980) for unstable conditions. The friction velocity , U^*, was used instead of W^*, when a stable surface layer

existed (20/0500). Values above tne inversion were set
to 10(-13) for both observed and predicted profiles.

f) The total predicted extinction at 8-12 um (Figure 7d)
was quite good outside of cloud layers. Again, values
above the inversion were set to the same value for both
observed and predicted profiles. The sensitivity of
aerosol size to relative humidity becomes larger wnen
the relative humidity is above 90%. Hence we expect
this comparison to be poor in the cloud region wnere tne
relative humidity approaches 100%. However, the good
agreement outside of clouds is encouraging.

g) The evaporation duct height (Z*) prediction (Figure
8b) is not very good. The disagreement occurs because
the predicted surface layer was more stable than was
observed. Z* increases almost linearly with increasing
stability. Very large Z* values were predicted at tne
end of the second period because it was stable and
because the predicted well mixed numidity was too low,
Figure 7a.

n) The predicted surface layer Cn2 values (Figure 8c.)
were always less than those observed because of the
previously mentioned inaccuracy in surface layer
stability. Minima at 19/2300, 20/1800 and 20/0500
correspond to the surface layer being neutral as it
passed from unstable to stable, unstable to stable and
stable to unstable conditions, respectively.

i.) The predicted surface layer aerosol scattering extinction for 8-12 um (Figure 8d) was very good during the second period. The observed and predicted decrease from 20/1800 to 21/1200 was associated with a decrease in relative humidity and wind speed. The wind speed used for the prediction was, of course, prescribed on the basis of observed results. Hence, the role of relative humidity on the extinction is that being evaluated.

C. PREDICTION INTERPRETATION AND APPLICATION

The demonstrated capability of this model, which is based on routinely observed input data, should be of assistance to the geophysics officer in estimating possible changes in the MABL and in the inversion and the potential impact upon tactically important parameters. Exploitation of the existing ducts is presently possible with IREPS. Specifically, the duct changes between elevated and surface based nature are of considerable concern to placement of platforms to enhance or to minimize communication links. Alerting commanders and airborne assets in advance to possible changes is a capability not previously available in on board assessment systems. Of additional use is the computation of the lifting condensation level to indicate the occurence of clouds.

IV. CONCLUSIONS

The importance of and an approach for predicting
evolutions of the marine atmospheric boundary layer have
been described. Changes in the mixed layer depth strengths
of overlying inversion and well-mixed properties lead to
significant changes in the weapons/systems tactical
environment. These include EM duct regions, optical
turbulence and optical extinction, both within and at the
boundaries of the inversion capped mixed layer.

Although the tactical descriptions are multi-variable
and require detailed vertical descriptions, a simplified
model based on routinely observed data appears to be quite
useful for predicting changes over 12-18 hours. For a cloud
topped period, it was demonstrated that the refraction,
optical turbulence and optical extinction profiles were
predicted quite well, as were cloud coverage changes.

The primary differences between observation and
predictions were for the near surface layer and pertain to
the evaporation duct height and the optical turbulence. The
predicted evaporation duct was much too high and the
predicted optical turbulence was much too low. In both
cases, the predicted air temperature was too high (2-3 C)
which resulted in a neutral to stable condition. The cause
for this appears to be due to improper specification of

cloud cooling within the mixed layer. This is an area in which research is still being performed.

Two schemes are presently being evaluated for specification of cloud top cooling and entrainment, Stage and Businger (1981) and Deardorff (1976). Both address entrainment and cloud top cooling for short and long wave radiation, but large disparities exist in actual parameterization. More study in the variance of absorption with insolation and cloud buoyancy should resolve the difference. Both of these effects may have great impact on the predicted results because of the bulk nature of the model employed.

Tactical decisions can only be made with timely, pertinent and accurate information. The specific information presented by this model can be extremely important to temporal and spatial variation of ducting and refraction. As a bulk model, it is a gross approximation to actual conditions, but affords decision makers an estimationof most probable relevant changes in the meteorological conditions.

APPENDIX A

OPERATING PROCEDURES FOR THE MODEL PROGRAM

MODEL USAGE PROCEDURES

1. Model Components and Flowchart

Using this code requires minimal knowledge of
microcomputer systems. Inputs required are an
initial radiosonde (IREPS), forecast winds (up to
30 hours), and subsidence (divergence) and
thermal advection. Because of forecasting, some
ability to estimate large scale subsidence and
advection is required.

1.1 Model Components.

A block diagram and flow chart for the program appear in
Fig. A-1 and A-2, respectively. The block diagram (Fig A-1)
gives an overview of the program operation and flow, as
broad as possible without specifics. The flow chart can be
useful to keep track of position within the execution of the
program. The program flow (Fig A-2) was designed to be as
autonomous as possible, yet enable the user to interface
with the precedure as deemed necessary. The two critical
points in program flow are the input of subsidence and
selecting an initial, simplified model for the atmospheric
structure (digitizing).

The following sections include separate discussion of
program operation, initial parameter input, selection of

output, and procedures for adjusting inputs to produce
meaningful output.

1.2 Overview of Model Flow

The first list of items for selection is the <u>DIRECTION</u>
<u>MENU</u> from which the user selects the operation to be
performed. The operation can be to:

1) Predict the change of the inversion,

2) Display the predicted results, graphics or tabular
form,

3) End prediction model and rewind tapes,

4) Return to IREPS,

5) Review or Change any initial conditions, then rerun
the prediction model.

Any data set on an IREPS data tape can be called. The
prediction would normally be the first choice in a
procedure. In the prediction procedure (choice 1), the
computation loop steps are:

1) Choose the IREPS data set,

2) Enter forecast winds and other initial conditions,

3) Approximate a stick structure to the temperature and
specific humidity profiles from the selected IREPS data
set.

Do not use IREPS bailout keys to correct errors.

EXCEPTION: User Defined Key 1 will take the user back
to the <u>DIRECTION MENU</u>.

Once all the computations have been performed for a forecast period, the program will return to the DIRECTION MENU. If the display (2.3) is selected at this point, the user may select displays of various computed values. Selection may be of the inversion height change and 'M' profiles at spaced intervals or the inversion strength 'jumps' and well-mixed temperature and specific humidity or a tabular print out of the computed parameters. After each of these displays are completed, the program will return to the DISPLAY MENU for a choice of different display or return to the DIRECTION MENU.

The user may also use the DIRECTION MENU to choose a different value for subsidence or other parameters by going through the REVIEW/CHANGE MENU. The prediction model must be run after changes are made to produce new outputs.

In the following section we will consider the program steps, the block diagram should be used to follow the discussion.
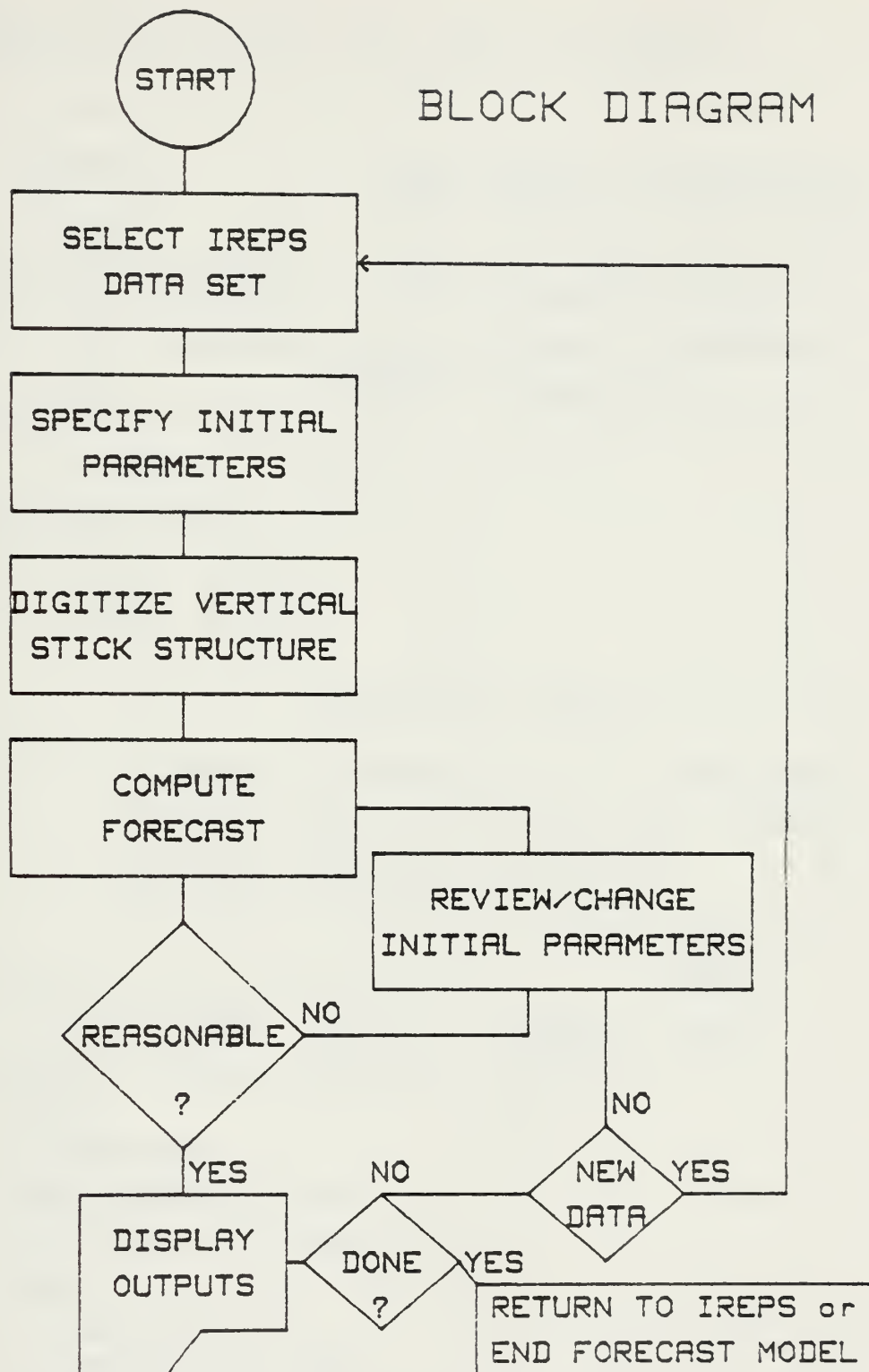
Fig. A-1. PROGRAM BLOCK DIAGRAM

PREDICTION FLOW CHART
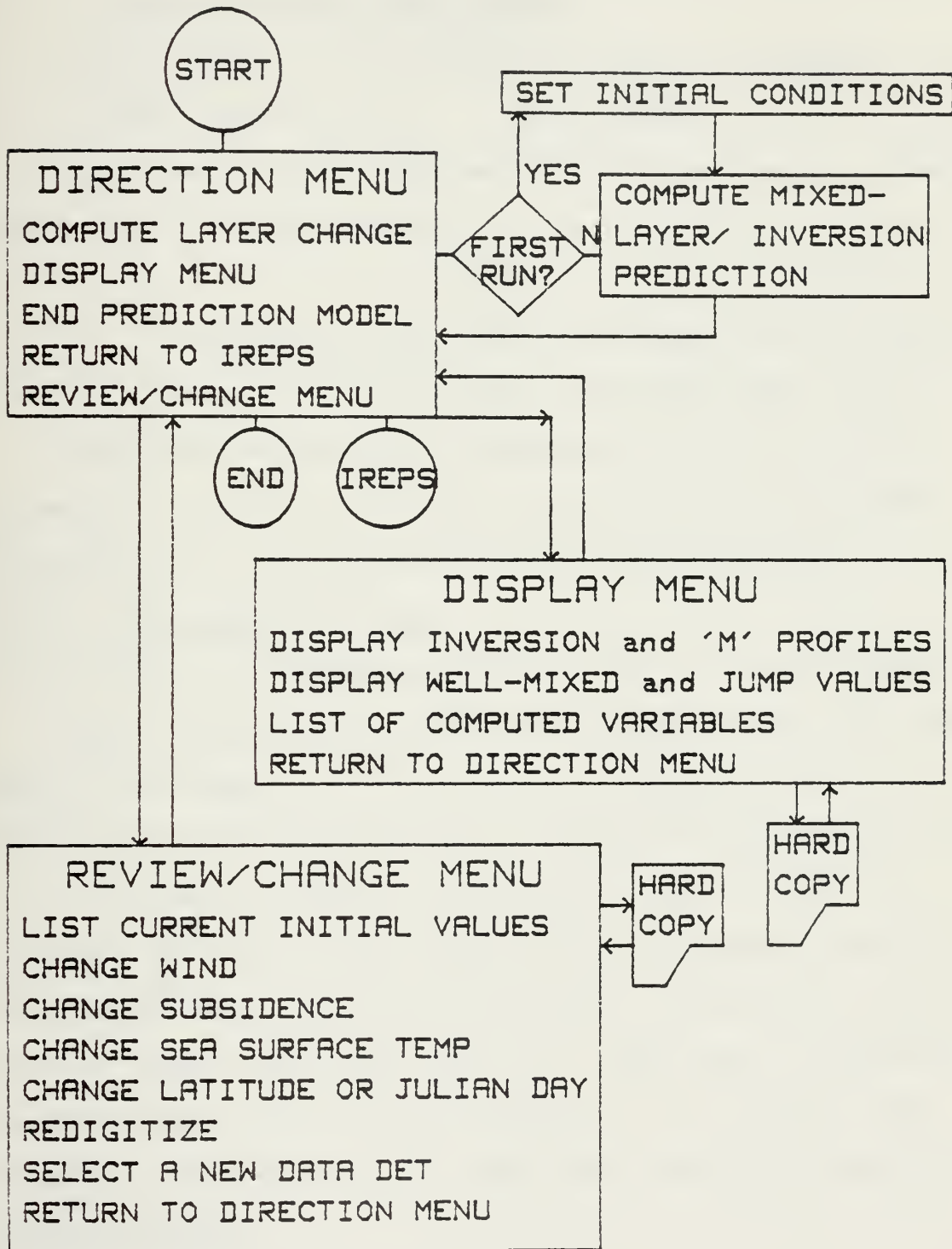
Fig. A-2. PROGRAM FLOWCHART

2.   PROGRAM EXECUTION STEPS

2.1.   Starting Procedures

2.1.1   Loading and Starting Program

The prediction model program is loaded by typing:

LOAD "MIXED2:xxx",1   then EXECUTE

Where xxx is the proper mass storage device (e.g. T14)
containing the model program.

NOTE

In default, the program will look for the data

tape to be in the left hand tape drive (T14).

Questions requiring user response will be set off by
asterisks, the selection menus can be viewed on the flow
diagrams or at the beginning of each major section.

2.1.2 Enter Execution Date

****

ENTER Execution Date as date of forecast run, just press
CONT if the same

****

The entered date will be printed on all displays to
indicate the date of run, this is not necessarily the date
of the data set. If it is left blank, the date will default
to that of the IREPS data set (i.e. IREPS date if IREPS has
just been run, blank if this program is run alone.) The
computer will then read the IREPS data table and display the
DIRECTION MENU.

DIRECTION MENU
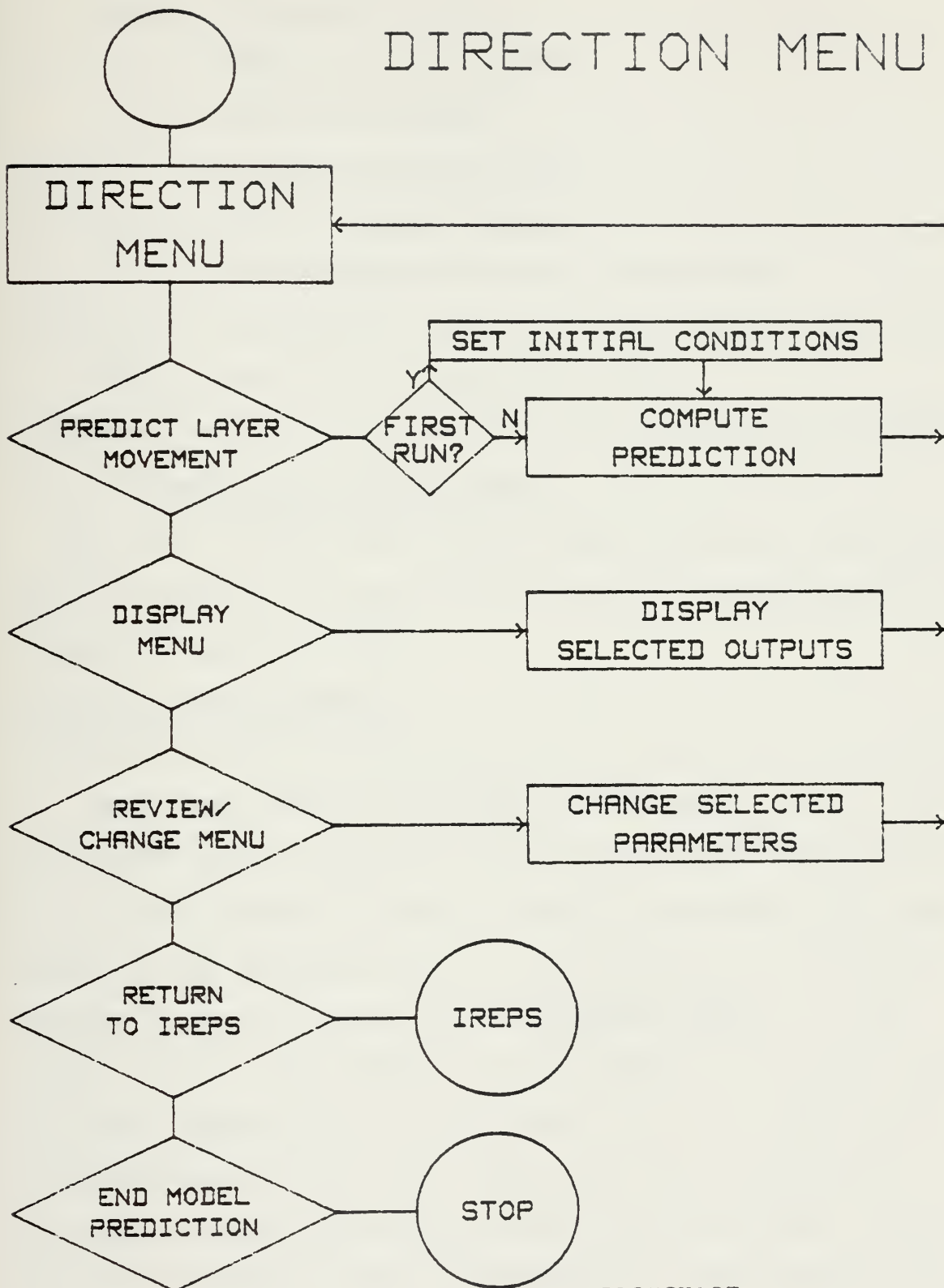
Fig. A-3. DIRECTION MENU FLOWCHART

2.2 DIRECTION MENU

Choices of procedures are:

   1)   COMPUTE THE LAYER CHANGE

   2)   DISPLAY THE OUTPUTS

   3)   END THE PREDICTION MODEL

   4)   RETURN TO IREPS PROGRAM

   5)   REVIEW/CHANGE ANY INITIAL CONDITIONS

****

ENTER option (1 to 5) then press CONT

****

2.2.1. COMPUTE THE LAYER CHANGE.

The list of data sets on the IREPS data tape is presented
and the selection is made by entering the corresponding line
number, followed by CONT.

2.2.1.1. Data Set Choice

****

ENTER THE NUMBER OF THE DATA SET DESIRED

****

If the desired data set is not on the present data tape,
hence is not displayed, SFK 1 (k1--top right of keyboard)
should be used to return to the DIRECTION MENU, or type
'CONT Option', then EXECUTE. If a different data tape is to
be used, insert it in the left tape drive and restart the
program with STOP and RUN. Otherwise, the program will
retrieve the entered choice of data set and proceed toward
the next procedure which is digitizing. The program will

ask for winds (2.2.1.4.), subsidence (2.2.1.5.) and the sea
surface temperature (2.2.1.6.).

2.2.1.2 Latitude and Julian Day

The program uses these two inputs for calculating the
zenith angle of the sun and thus the amount of insolation at
the top of the inversion or cloud layer.

****

ENTER Latitude of the prediction area [-90 to 90] [use -
for South]

****

ENTER the Julian day of the year [maximum 3 digits]

****

2.2.1.3 Beginning Time

****

ENTER THE BEGINNING TIME [4 digits]

****

The beginning time will be displayed on all the output.
The entered time should be fairly close to the start time
since it determines the beginning of the 30 hour forecast
period.   The entered time must have four characters (e.g.
1900).   The program displays will only be in whole hour
segments for easier graphic interpretation.

2.2.1.4 Wind Forecast

****

IS THIS WIND FROM IREPS OKAY (Y/N)?

****

The program will display the initial time and the wind speed as previously entered in the IREPS data set. If the wind is to stay the same, press CONT with no entry, the response will default to the first of the options. If the wind is to be changed, enter ´N´, press CONT, in which case the following question will ask for a new beginning wind speed.

****

ENTER BEGINNING WIND SPEED [KNOTS] at time XXXX

****

Winds are requested in KNOTS. The code performs computations with wind in m/s, a conversion is performed, (c.f. Appendix C.) The display is now set up to enter forecast winds for the period. (Fig B-1)

****

nhmm,ww   FROM THE FORECAST , ENTER: TIME ,WIND (KNOTS)

****

The maximum number of winds USED is 10. When done entering winds, enter ´E´ or ´END´. Winds will be linearly interpolated between input times. This is a gross approximation, but works well with the degree of accuracy used in forecasting winds. To get a smoothing closer to the forecast, enter more winds at the times of rapid change. If the fine structure is available or needed only for the first part of the period, enter the winds as desired. If the last

wind entered is for a time before the end of the period it will be held constant to the end of the period.

If the initial wind is to be used throughout the period, enter 'E' or 'END' as the first response to this question. As a prompt, the time of the last possible input period, 30 hours after the beginning time, is displayed. All times must be entered sequentially, times beyond the last period will not be considered.

****

    DO THESE WINDS LOOK OKAY (Y/N)?

****

If different winds are desired, the computer will ask for correction of entered winds, one line at a time. If the displayed winds are correct, press CONT, if not, enter J and refer to the previous qestion. The next requests will be for subsidence, and a check of sea surface temperature. The program flow will then proceed to digitizing.

2.2.1.5. Subsidence Forecast

****

    ENTER SUBSIDENCE (m/sec) [First value=-.003], or CONT to use same value?

****

Enter a value of subsidence in meters per second. This can be calculated from the divergence field, determined explicitly from the previously used value or by manipulating this model between successive soundings.

2.2.1.6.   Sea Surface Temperature Specification

****

ENTER THE SEA SURFACE TEMP IN ´C or just CONT for same
value

****

The sea surface temperature from IREPS, which is
displayed, may need refinement from tne initially entered
value.   This would arise if the temperature used in tne
IREPS data set was the sea water injection temperature.   To
use the existing value, just press CONT without entering
anything. To change the value, enter tne new temperature in
degrees centigrade, and press CONT.

2.2.1.7 Profile Initialization

The program will now go to the digitizing, the
determination of the vertical structure of potential
temperature and specific humidity.   The steps establish:

Inversion height

Potential temperature

(well-mixed, jump and lapse rate values)

Specific humidity

(Well-mixed, jump and lapse rate values)

Previous inputs will be dislayed on tne plot. One
display with data and digitized results appears in Fig.B-2.
At the end the user will be asked to specify wnether tne
plotting is OKAY or if he wants to do it AGAIN, if an error

is made during the digitizing routine, continue to this question, then redigitize.

The program will draw out the digitizing graph and its labels, then enter the digitizing mode. The first structure to plot will be the potential temperature, the second will be the specific humidity. The profile data, taken from the IREPS data tape, will be displayed to 2400 meters or the maximum height of entered data if less than 2400 meters. When digitizing can begin, the computer will beep and a full screen cursor will appear. To position the cursor, use the arrow keys at the top, center of the keyboard, then CONT.

NOTE

Finer structure is achieved by using shift when positioning the cursor. This will move it one pixel, or picture element, at a time.

2.2.1.7.1. POTENTIAL TEMPERATURE: θ

la) Inversion Height: position the horizontal line at a representative inversion height (usually near the middle of the sharp temperature ´jump´.)

lb) Well-mixed Temperature: position the vertical line at a representative value for the well-mixed temperature below the inversion, then CONT. POINT 1

2) Inversion ´jump´: horizontally position the small cursor at the point where the

extension of the profile above the layer meets
the horizontal 'jump' line at the inversion
height (use precision eyeball), then CONT.
POINT 2

3) Gradient Above the Inversion: position the
small cursor at the top of the screen or
highest data point to get the best linear
approximation of potential temperature above
inversion, determining lapse rate, then press
CONT. POINT 3

2.2.1.7.2. SPECIFIC HUMIDITY: Q

1a) The inversion height determined for the
potential temperature sequence will be the same
for the specific humidity procedure. POINT 4

1b) Well-mixed Specific Humidity: position the
vertical line at a representative value for the
structure below the inversion, then CONT. POINT 4

2) Inversion 'jump': position the cursor where
the extension of the profile above meets the
horizontal 'jump' at the inversion (again, this
is very subjective), then CONT. POINT 5

3) Gradient Above the Inversion: position the
small cursor at the top of the screen or highest
data point to get the best linear approximation
of the specific humidity above the inversion,
determining lapse rate, then press CONT. POINT 6

ENVIRON. DATA LIST. FROM MIXED2   NPS   05 20 78/0430

WIND   6.7   AIR TEMP   11.3
SEA TEMP   15.0   REL HUM   97.7
SFC PRESS   1013.1   IREPS EVAP DUCT HT   5.9

LEVEL	PRESS	TEMP	RH %	METERS	M UNITS	POTENT TEMP	SPEC HUM
1	1013.1	10.9	93.0	6.0	334	11.0	7.3
2	1000.0	10.7	93.0	114.7	347	11.8	7.2
3	972.0	9.0	93.0	351.2	372	12.4	6.4
4	954.0	11.1	22.0	506.7	353	16.1	1.7
5	947.0	18.4	20.0	568.9	360	24.0	2.5
6	944.0	18.9	20.0	596.0	363	24.7	2.6
7	923.0	19.4	19.0	789.0	387	27.1	2.6
8	850.0	14.9	24.0	1490.9	481	29.5	2.4
9	754.0	9.9	19.0	2494.7	609	34.3	1.4
10	700.0	7.3	19.0	3109.3	691	38.3	1.2
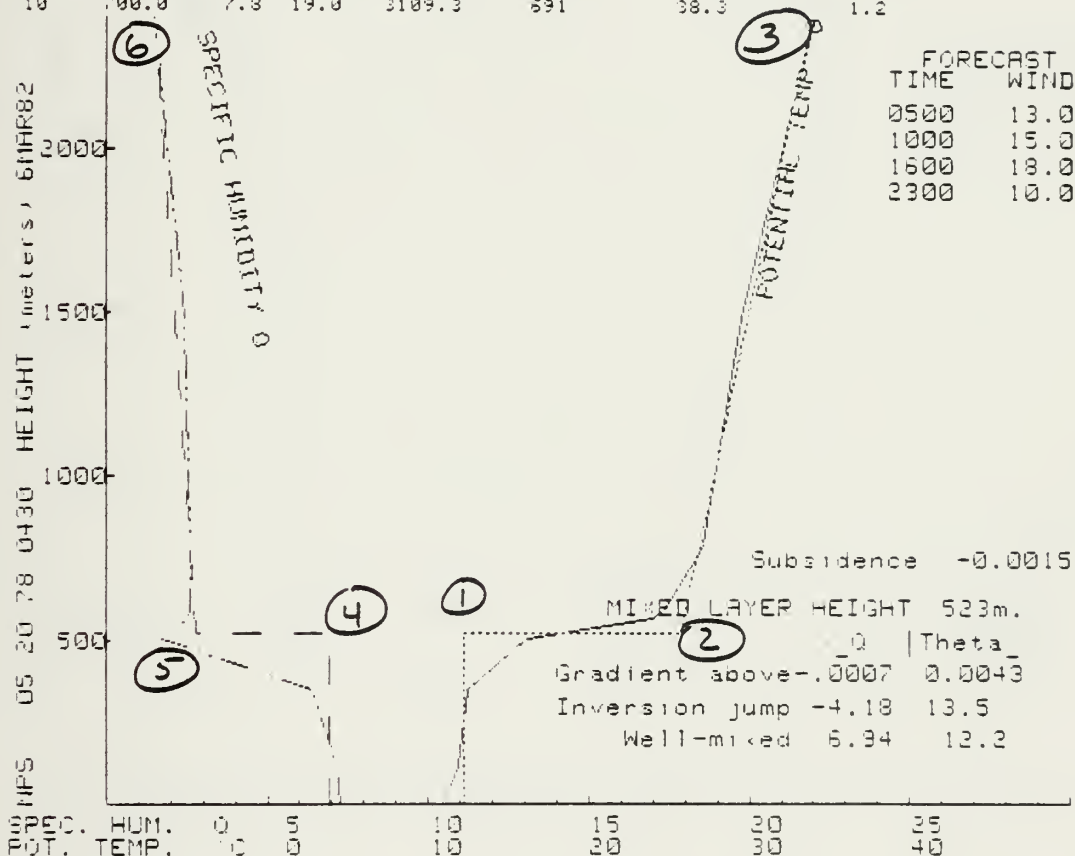
FORECAST
TIME   WIND
0500   13.0
1000   15.0
1600   18.0
2300   10.0

Subsidence   -0.0015

MIXED LAYER HEIGHT 523m.
                        Q |Theta
Gradient above -.0007 0.0043
Inversion jump -4.18 13.5
Well-mixed 6.94   12.2

| SPEC. HUM. | 0 | 5 | 10 | 15 | 20 | 25 |
| POT. TEMP. | -10 | 0 | 10 | 20 | 30 | 40 |

Fig. A-4. EXAMPLE OF DIGITIZED VERTICAL STRUCTURE

WIND   5.1   AIR TEMP   23.9
SEA TEMP   15.0   REL HUM   60.0
SFC PRESS   1013.1   IREPS EVAP DUCT HT 22.6

LEVEL	PRESS	TEMP	RH %	METERS	M UNITS	POTENT TEMP	SPEC HUM
1	1013.0	23.9	58.0	5.9	338	24.0	10.4
2	1000.0	19.9	70.0	118.2	354	21.1	9.9
3	976.0	16.5	83.0	325.3	382	19.7	9.4
4	954.0	14.9	79.0	520.3	399	20.0	8.0
5	929.0	14.9	56.0	745.9	410	22.2	5.7
6	907.0	15.7	53.0	949.2	435	25.0	5.7
7	879.0	14.4	41.0	1214.3	458	26.3	4.3
8	850.0	14.0	26.0	1497.9	484	28.7	2.5
9	807.0	12.9	10.0	1934.3	529	31.9	.9
10	765.0	11.1	10.0	2381.0	589	34.4	.8
11	717.0	8.4	10.0	2918.3	661	37.0	.7
12	700.0	9.2	10.0	3116.6	687	39.7	.7
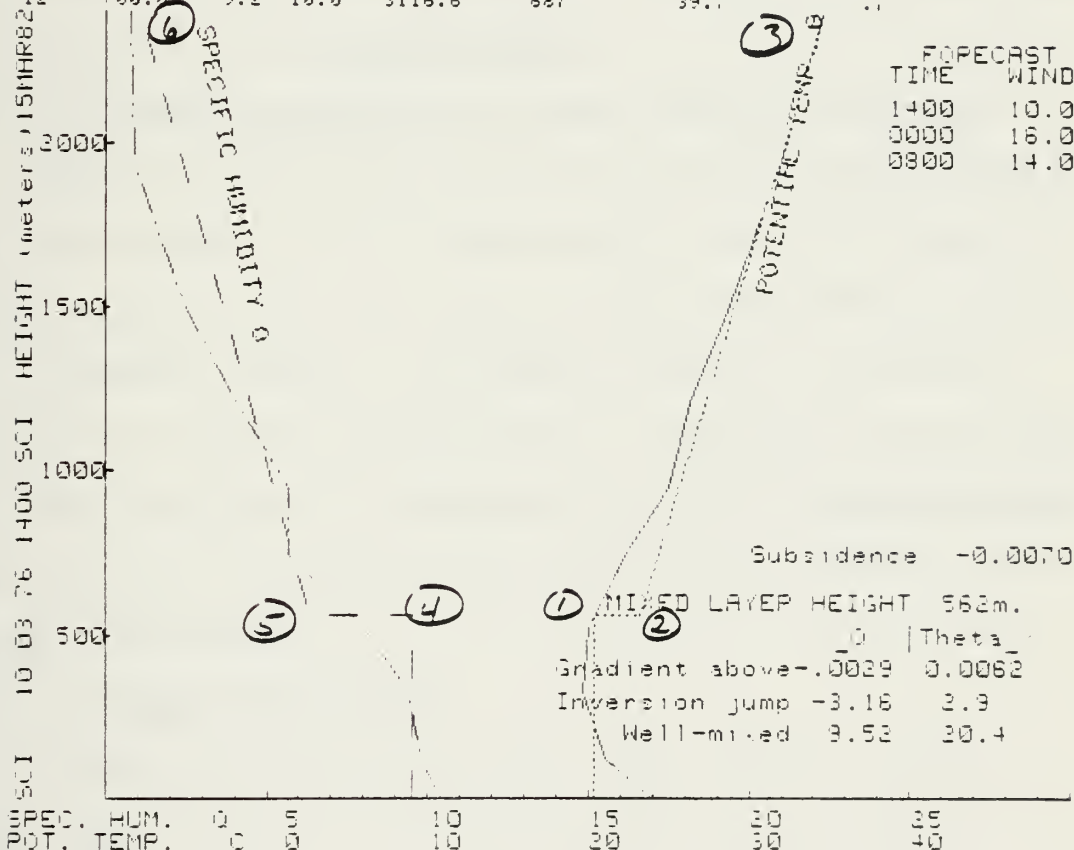
Fig. A-5. EXAMPLE OF DIGITIZED VERTICAL STRUCTURE

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If the digitized plot is not as desired, move the cursor to AGAIN, press CONT, and begin with POTENTIAL TEMPERATURE (2.2.1.6.1). If the digitized plot is agreeable, move the cursor to the OKAY and press CONT. This will start the program into the computing stage. A picture of the layer computatutions is progressively displayed.

At the completion of the run the program will return to the DIRECTION MENU. The running prediction may be PAUSEd at any time, then k1 or 'CONT Option', 'EXECUTE' will take the program back to the DIRECTION MENU.

2.2.1.8. Change Subsidence or Other Initial Parameters

A decision point exists here as to the reasonableness of the layer movement. If it looks good, choose to display the change (2.2.2.). If the results of the computation do not go as expected, choose to re-compute using a new value of subsidence or other initial data, or redigitize the vertical structure. Both can be performed by choosing REVIEW/CHANGE MENU (2.2.5.). Use of the flow chart can be helpful when running the program.

2.2.2. Display the Outputs

Selection of this option will take the user to the DISPLAY MENU for more defined and varied displays of computed inversion layer movement:

1) overall display of inversion movement and M-profiles

2) the inversion jumps of temperature and humidity

3) tabulation of selected values through the period

Refer to paragraph 2.3 DISPLAY MENU

2.2.3. End Prediction Model and Rewind the Tapes

This choice will simply rewind the tapes in the computer and end the prediction model program. Remember to use the EJECT bar to remove tapes.

2.2.4. Return to IREPS

This choice will take the user back to the IREPS program. The IREPS driver tape must be in the right hand tape drive, before pressing CONT, to load successfully.

2.2.5. REVIEW/CHANGE MENU

This option is for rerunning the program with different values for initial data. This can also be used for going through the digitizing routine and retaining the winds that were input. When the end of the digitizing routine is reached, the user will again be given the choice of changing the digitized points. If all looks satisfactory, press CONT which will return the program to this menu. This procedure can be continued until a good approximation is generated.

DISPLAY MENU
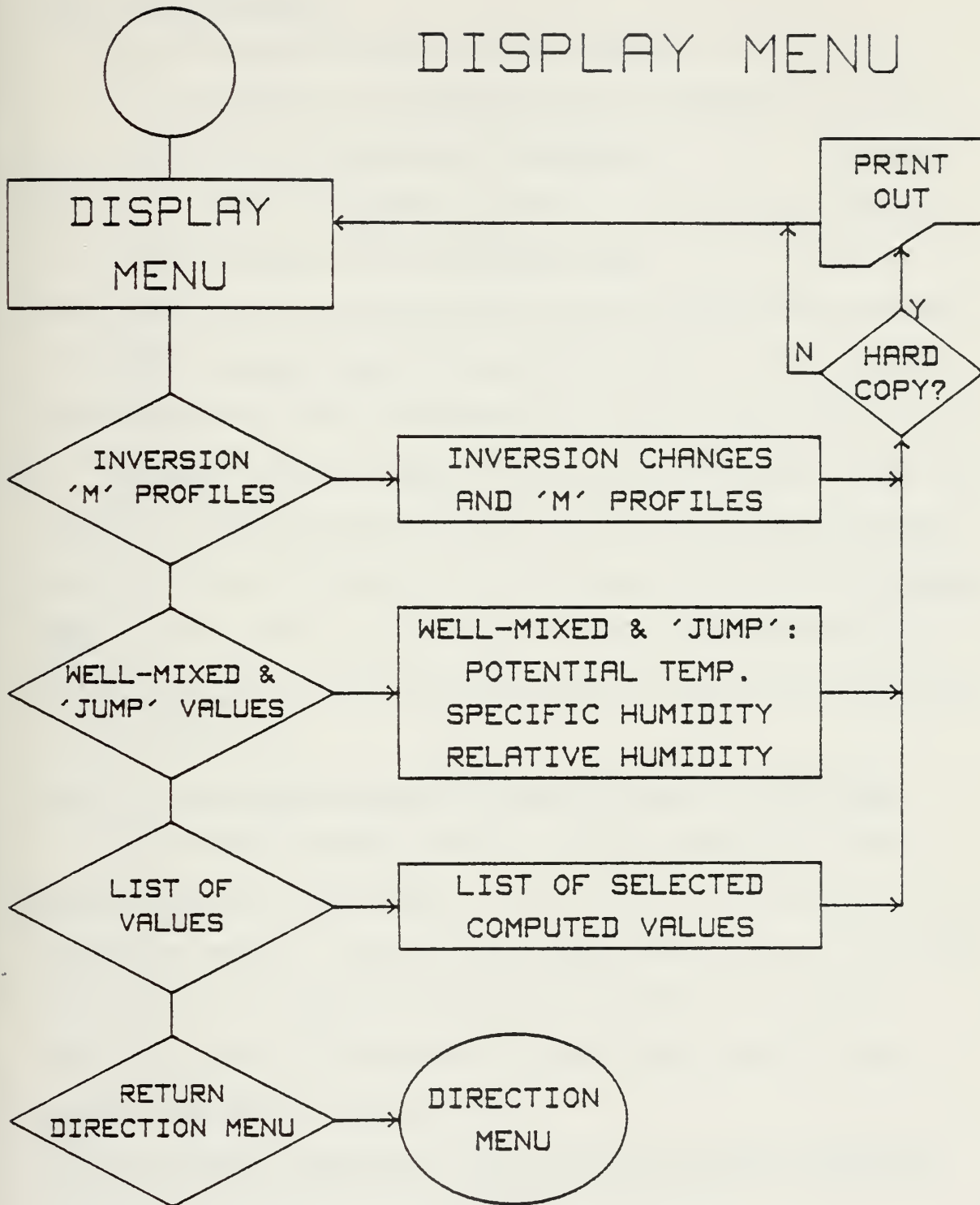
Fig. A-6. DISPLAY MENU FLOWCHART

2.3. DISPLAY MENU

Tne following cptions will be listed:

1 DISPLAY OF INVERSION AND 'M' PROFILES   graphics

2 'JUMP' STRENGTH AT INVERSION   graphics

3 LIST OF COMPUTED VALUES   tabular

4 RETURN TO THE DIRECTION MENU

****

ENTER display choice then press CONT

****

The user will be asked of he wants nard copy, after tne
grapnics displays are drawn and before the tabular listing
is run. Option 4 will take the program oack to tne <u>DISPLAY
MENU</u> as will SFK 1 at any time. Further discussion and
interpretation of the various aspects of the displays occurs
in Appendix B.

2.3.1. Graphics Display of Inversion and 'M' Profiles

As the main graphic product of the prediction, this
display depicts the cnanges, over tne 30 hour period, in tne
inversion neignt, the lifting condensation level (for cloud
formation), tne relative humidity and tne 'M' profile
(modified index of refraction) indicating elevated and
surface based duct conditions.

2.3.2 Graonic Display of Jumps and Well-Mixed Values of Potential Temperature and Specific Humidity

To illustrate the change in inversion strength, tnis
display grapnically snows the variations in tne well-mixed

values next to the 'jump' values of both potential
temperature and specific humidity. Also displayed is the
relative humidity as it evolved through the forecast period.

2.3.3 Tabular Display of Selected Parameters

This option lists the values that are stored during
computation to be used for generating graphic displays. They
are useful to more fully understand the movement of the
inversion, the change in the duct area and the inversion
strength.

2.3.4 Return to the DIRECTION MENU

This option will return the program to the DIRECTION
MENU for further choices to compute again, return to the
IREPS program or just end the prediction model.
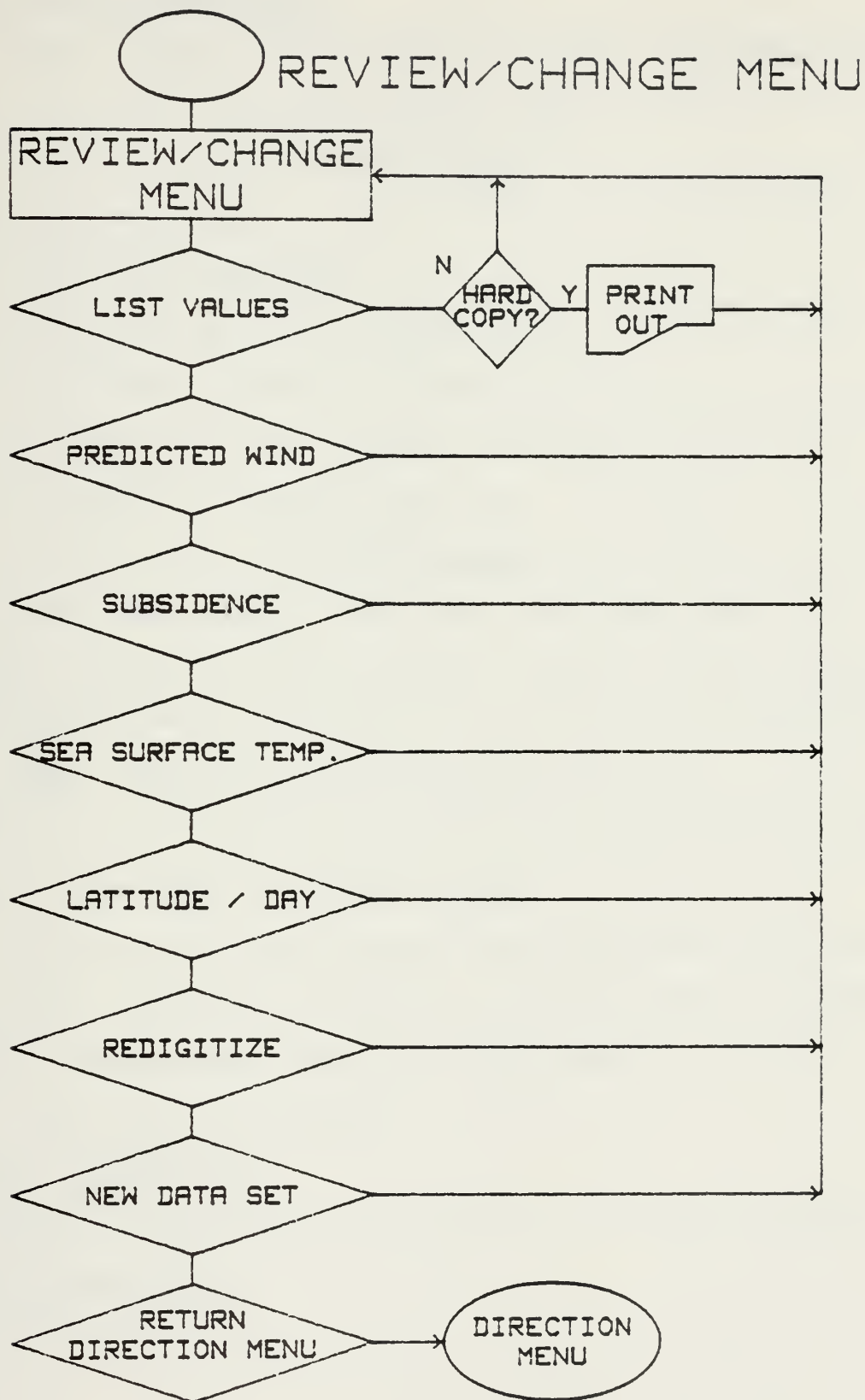
Fig. A-6.   REVIEW/CHANGE MENU

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2.4   REVIEW/CHANGE MENU

Select one of the following to change a parameter after which the prediction needs to run again:

1) List Current Initial Values

2) Change Wind

3) Change Subsidence

4) Change Sea Surface Temperature

5) Change Latitude or Julian Day

6) Redigitize the Vertical Structure

7) Select a different data set

8) Return to the DIRECTION MENU

Once this option is exercised, the model must run through another prediction before drawing out any displays.

****

ENTER choice from REVIEW/CHANGE MENU (1-8)

****

2.4.1. List Current initial Values

This will list the values of the indicated variables that were last used or modified. The user will be preompted to get a hard copy. Default of the question will be to the CRT, press CONT when ready.

2.4.2. Change Wind

Refer to procedure 2.2.1.3 and 2.2.1.4 and the return to REVIEW/CHANGE MENU.

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2.4.3.   Change Subsidence

     Refer to procedure 2.2.1.5, return to REVIEW/CHANGE MENU

2.4.4.   Change Sea Surface Temperature

     Refer to procedure 2.2.1.6, return to REVIEW/CHANGE MENU

2.4.5.   Change Latitude or Julian Day

     Refer to procedure 2.2.1.2, return to REVIEW/CHANGE MENU

2.4.6.   Redigitize the Vertical Structure

     Refer to procedure 2.2.1.7, return to REVIEW/CHANGE MENU

2.4.7.   Select a New Data Set

     Choosing a new data set will take the program through

all the initial steps to set up the necessary parameters to

make a prediction model run.

2.4.8.   Return to DIRECTION MENU

     This option will return the program to the DIRECTION

MENU for further choices to compute the forecast again,

return to the IREPS program or end the prediction model.

PREDICTION OUTPUT

This appendix contains examples of the prediction output which are obtained by making selections from the DISPLAY MENU for output. Two different prediction runs are shown, each for a different observational period. The two periods were a cloud covered case, previously discussed in the body of the thesis, and a clear sky case, described by Davidson et al (to be submitted, JAM, 1982).

Entrainment energetics for the cloud covered case in this appendix were based on fomulations by Stage and Businger (1981). Results for the same period were shown in the body of the thesis, but were based on a formulation by Deardorff (1976). The scope of this thesis was not to compare the differences between the entrainment parameterizations. Such a comparison will be performed separately by Naval Postgraduate School investigators.

Prediction output examples appear in two sets, one for each prediction period. Each set contains a listing of several computed variables and two pages with graphic plots of several computed variables and/or profiles. The plotted variables do not encompass all those listed. All selected outputs automatically appear on the CRT, and the printed copies (hard copy) may be obtained by selecting the appropriate option after CRT display.

The listing of predicted results (Fig. B-3 and B-6) are
self-explanatory. The listed values are for every 30 minute
period (the prediction time step) and the units are:
velocity-m/s, temperature-Kelvin, height-m and
humidity-g/kg.

The graphic plots contain information about the
predicted vertical structure (Fig. B-1 and B-4) and the
predicted values in the mixed-layer and at the inversion
(Fig. B-2 and B-5).

The predicted vertical structure is presented in two
panels in Fig. B-2 and Fig. B-4. The top panel shows
predicted M profiles (Modified index of refraction) at 6
hour intervals, including possible surface based duct
conditions. It is determined from the predicted well-mixed T
and q and the predicted jumps at and lapse rates above the
inversion. The bottom panel shows the top of the well mixed
layer (-----), the top of the inversion zone (- - -)
assuring an inversion thickness of .1 layer height and the
lifting condensation level (.....). The lifting condensation
level was computed from the well mixed temperature and
specific humidity values. A description of duct
determination appears at the bottom of the hard copy page.

The graphic display of predicted values (Fig. B-2 and
Fig. B-5) in the mixed layer and at the inversion are of
several variables appearing in the listing option. The
solid lines in the top panel represent the well mixed values

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in the layer appropriate for tne 10 meter level. The dashed
lines are the ´jump´ of that parameter (T or q) at tne
inversion. The ´jump´ magnitudes are important in
determining the strength of the duct and its depth. The
bottom panel shows the relative humidity at the 10-meter
level.   It can be used to determine the proximity of fog or
clouds and would be important in aerosol equilibrium size
determination.

Fig. B-1. Vertical Profile and 'M'' Profiles- Cloudy Sky

Fig. 3-2. Mixed Layer and 'Jump' Values-Cloudy Sky

This is a list of plotted values. NPS   05.20/78/0430   6MAR82

HOUR	Zi	Zicl	ReiHum	WIND	Th	Qp	Thv	Dth	Dthv	Dqp
0500	526	380	79.7	6.7	12.1	7.0	13.3	13.6	12.9	-4.2
0530	530	352	80.6	6.8	12.0	7.1	13.3	13.7	12.9	-4.3
0600	534	330	81.4	6.9	12.0	7.1	13.2	13.3	13.0	-4.4
0630	539	312	81.9	7.0	12.0	7.2	13.3	13.3	13.0	-4.4
0700	544	301	82.1	7.1	12.1	7.2	13.3	13.3	13.0	-4.5
0730	549	296	82.1	7.2	12.1	7.2	13.4	13.7	12.9	-4.5
0800	555	297	81.9	7.3	12.2	7.3	13.5	13.6	12.9	-4.5
0830	560	301	81.6	7.4	12.4	7.3	13.6	13.5	12.7	-4.6
0900	566	310	81.1	7.5	12.6	7.3	13.8	13.4	12.6	-4.6
0930	571	320	80.6	7.6	12.7	7.4	14.0	13.3	12.5	-4.7
1000	577	333	80.1	7.7	12.9	7.4	14.1	13.2	12.3	-4.7
1030	582	346	79.5	7.9	13.0	7.4	14.3	13.0	12.2	-4.7
1100	587	359	79.0	8.0	13.2	7.5	14.5	12.9	12.0	-4.8
1130	591	371	78.6	8.1	13.3	7.5	14.7	12.8	11.9	-4.8
1200	596	382	78.2	8.2	13.5	7.5	14.8	12.6	11.8	-4.8
1230	600	392	77.9	8.4	13.6	7.6	14.9	12.5	11.7	-4.9
1300	605	400	77.6	8.5	13.7	7.6	15.1	12.5	11.6	-4.9
1330	609	406	77.5	8.6	13.8	7.6	15.2	12.4	11.5	-5.0
1400	614	410	77.4	8.8	13.9	7.7	15.2	12.3	11.5	-5.0
1430	618	412	77.4	8.9	14.0	7.7	15.3	12.3	11.4	-5.0
1500	623	411	77.5	9.0	14.0	7.7	15.4	12.3	11.4	-5.1
1530	627	409	77.7	9.1	14.0	7.7	15.4	12.3	11.4	-5.1
1600	632	405	78.0	9.3	14.0	7.8	15.4	12.4	11.5	-5.1
1630	638	399	78.3	9.0	14.0	7.8	15.4	12.4	11.5	-5.2
1700	643	392	78.6	8.7	14.0	7.8	15.3	12.5	11.6	-5.2
1730	649	383	79.0	8.4	13.9	7.8	15.3	12.6	11.7	-5.2
1800	655	374	79.4	8.1	13.8	7.8	15.2	12.7	11.8	-5.2
1830	662	366	79.7	7.8	13.8	7.8	15.1	12.8	11.9	-5.2
1900	668	359	79.9	7.5	13.7	7.8	15.1	12.9	12.0	-5.2
1930	675	352	80.1	7.2	13.6	7.8	15.0	13.0	12.1	-5.2
2000	682	348	80.2	6.9	13.6	7.8	14.9	13.1	12.2	-5.2
2030	689	345	80.3	6.6	13.5	7.8	14.9	13.2	12.3	-5.2
2100	696	343	80.4	6.3	13.5	7.7	14.8	13.3	12.4	-5.2
2130	702	341	80.4	6.0	13.4	7.7	14.8	13.4	12.5	-5.1
2200	709	340	80.4	5.7	13.4	7.7	14.8	13.5	12.6	-5.1
2230	715	339	80.4	5.4	13.4	7.7	14.7	13.6	12.7	-5.1
2300	721	339	80.4	5.2	13.3	7.7	14.7	13.6	12.8	-5.1
2330	727	339	80.4	5.2	13.3	7.6	14.6	13.7	12.8	-5.1
0000	733	338	80.5	5.2	13.2	7.6	14.6	13.8	12.9	-5.1
0030	739	338	80.5	5.2	13.2	7.6	14.5	13.9	13.0	-5.1
0100	745	338	80.5	5.2	13.1	7.6	14.5	14.0	13.1	-5.0
0130	751	337	80.5	5.2	13.1	7.6	14.4	14.1	13.2	-5.0
0200	756	337	80.5	5.2	13.1	7.5	14.4	14.1	13.3	-5.0
0230	762	337	80.5	5.2	13.0	7.5	14.4	14.2	13.3	-5.0
0300	767	337	80.5	5.2	13.0	7.5	14.3	14.3	13.4	-5.0
0330	773	337	80.5	5.2	13.0	7.5	14.3	14.3	13.5	-5.0
0400	778	337	80.5	5.2	13.0	7.5	14.3	14.4	13.5	-5.0
0430	783	337	80.5	5.2	12.9	7.5	14.2	14.5	13.6	-5.0
0500	789	337	80.5	5.2	12.9	7.5	14.2	14.5	13.7	-5.0
0530	794	337	80.5	5.2	12.9	7.4	14.2	14.6	13.7	-5.0
0600	799	337	80.4	5.2	12.9	7.4	14.2	14.6	13.8	-5.0
0630	804	338	80.3	5.2	12.9	7.4	14.2	14.7	13.8	-5.0
0700	809	341	80.0	5.2	12.9	7.4	14.2	14.7	13.8	-5.0
0730	814	346	79.7	5.2	12.9	7.4	14.2	14.7	13.8	-5.0
0800	818	354	79.3	5.2	13.0	7.4	14.3	14.7	13.8	-5.0
0830	823	364	78.8	5.2	13.1	7.4	14.4	14.6	13.7	-5.0
0900	827	376	78.2	5.2	13.2	7.4	14.5	14.5	13.7	-5.0
0930	831	390	77.6	5.2	13.3	7.4	14.6	14.5	13.6	-5.0
1000	835	405	76.9	5.2	13.4	7.4	14.7	14.4	13.5	-5.0
1030	838	420	76.3	5.2	13.5	7.4	14.9	14.3	13.4	-5.0
1100	842	439	75.6	5.2	13.7	7.4	15.0	14.2	13.3	-5.0
HOUR	Zi	Zicl	ReiHum	WIND	Th	Qp	Thv	Dth	Dthv	Dqp

Fig. B-3.   List of Predicted Values-Cloudy Sky
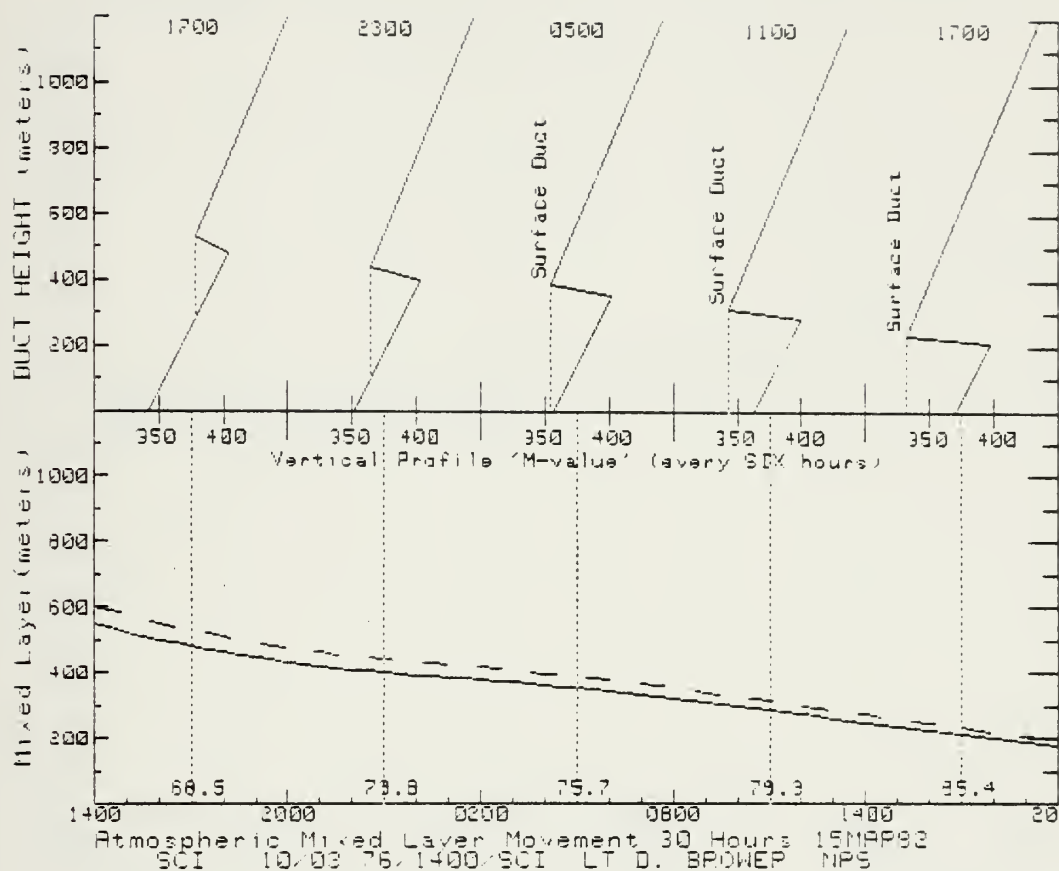
The possibility of a surface based duct (SBD) is indicated and only
due to the 'M' value greater at the surface than at the inversion
height. Variation in the vertical structure must be emphasized
when briefing this forecast in that a SBD may not exist.

This is a SIMPLIFICATION of the real structure.

This display is divided into UPPER and LOWER windows:
LOWER WINDOW displays the top and middle of the elevated layer and its
    forecast continued movement for a thirty hour period after beginning.
At the bottom is the Relative Humidity at each six hour period.
The lightly dotted line is the lifting condensation level.
    [With enough moisture near the inversion, this can be used
    as a flag for possible cloud formation, or for high mixed-
    layer humidity, near the surface, to forecast fog.]
UPPER WINDOW picks out M-value structure (using only 4 points)
    at each six hour period and will indicate a surface based duct
    only if the elevated M-value is less than or within 5 of
    the surface M-value. The sampled times are displayed at top.

Fig. 3-4. Vertical Profile and 'M' Profiles- Clear Sky

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Fig. B-5. Mixed Layer and 'Jump' Values-Clear Sky

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This is a list of plotted values. SCI   10/03/76/1400/SCI   15MAR82

HOUR	Zi	Zicl	RelHum	WIND	Th	Qp	Thv	Dth	Dthv	Dqp
1400	549	805	64.7	5.1	20.4	9.7	22.2	2.8	2.2	-3.3
1430	536	787	65.3	5.3	20.5	9.8	22.3	2.7	2.1	-3.5
1500	524	768	66.0	5.5	20.6	10.0	22.4	2.7	2.0	-3.7
1530	512	750	66.6	5.6	20.7	10.2	22.6	2.6	1.9	-3.9
1600	501	732	67.2	5.8	20.8	10.3	22.7	2.6	1.8	-4.0
1630	491	714	67.9	5.9	20.9	10.5	22.8	2.5	1.7	-4.2
1700	481	697	68.5	6.1	21.0	10.6	22.9	2.4	1.6	-4.4
1730	472	681	69.1	6.2	21.1	10.8	23.1	2.4	1.5	-4.6
1800	463	665	69.6	6.4	21.2	10.9	23.2	2.3	1.5	-4.7
1830	454	650	70.2	6.5	21.3	11.1	23.3	2.3	1.4	-4.9
1900	447	635	70.7	6.7	21.4	11.2	23.4	2.2	1.3	-5.1
1930	439	622	71.2	6.9	21.5	11.4	23.6	2.1	1.2	-5.2
2000	432	609	71.7	7.0	21.6	11.5	23.7	2.1	1.1	-5.4
2030	426	597	72.1	7.2	21.7	11.7	23.8	2.0	1.0	-5.6
2100	420	586	72.5	7.3	21.8	11.8	23.9	2.0	1.0	-5.7
2130	414	575	72.9	7.5	21.9	11.9	24.0	2.0	.9	-5.8
2200	409	566	73.2	7.6	22.0	12.0	24.1	1.9	.8	-6.0
2230	404	558	73.5	7.8	22.1	12.1	24.2	1.9	.8	-6.1
2300	400	550	73.8	7.9	22.1	12.2	24.3	1.9	.7	-6.3
2330	396	544	74.0	8.1	22.2	12.3	24.4	1.8	.7	-6.4
0000	392	538	74.2	8.2	22.3	12.4	24.5	1.8	.6	-6.5
0030	389	533	74.4	8.2	22.4	12.5	24.6	1.8	.6	-6.6
0100	385	528	74.6	8.1	22.4	12.6	24.7	1.8	.5	-6.7
0130	382	524	74.7	8.1	22.5	12.7	24.8	1.8	.5	-6.8
0200	379	521	74.8	8.0	22.6	12.7	24.9	1.8	.5	-6.9
0230	374	518	75.0	7.9	22.6	12.8	24.9	1.8	.5	-7.0
0300	371	515	75.1	7.9	22.7	12.9	25.0	1.8	.5	-7.1
0330	366	511	75.3	7.8	22.7	12.9	25.1	1.7	.5	-7.2
0400	362	508	75.4	7.7	22.8	13.0	25.1	1.7	.4	-7.3
0430	358	504	75.6	7.7	22.8	13.1	25.2	1.8	.4	-7.3
0500	353	500	75.7	7.6	22.9	13.1	25.2	1.8	.4	-7.4
0530	348	496	75.9	7.5	22.9	13.2	25.3	1.8	.4	-7.5
0600	343	491	76.1	7.5	22.9	13.3	25.3	1.8	.4	-7.6
0630	338	486	76.4	7.4	23.0	13.3	25.4	1.8	.4	-7.7
0700	333	480	76.6	7.3	23.0	13.4	25.4	1.8	.4	-7.7
0730	327	474	76.9	7.3	23.0	13.5	25.4	1.8	.4	-7.8
0800	321	467	77.2	7.2	23.0	13.5	25.5	1.8	.4	-7.9
0830	316	460	77.5	7.2	23.1	13.6	25.5	1.8	.3	-8.0
0900	310	453	77.8	7.2	23.1	13.7	25.5	1.8	.3	-8.1
0930	304	445	78.1	7.2	23.1	13.7	25.6	1.8	.3	-8.2
1000	298	436	78.5	7.2	23.1	13.8	25.6	1.8	.3	-8.3
1030	292	427	78.9	7.2	23.1	13.9	25.6	1.8	.3	-8.4
1100	286	417	79.3	7.2	23.1	14.0	25.7	1.8	.3	-8.4
1130	279	407	79.7	7.2	23.2	14.1	25.7	1.8	.3	-8.5
1200	273	397	80.2	7.2	23.2	14.2	25.7	1.9	.3	-8.6
1230	267	386	80.6	7.2	23.2	14.2	25.7	1.9	.3	-8.7
1300	261	374	81.1	7.2	23.2	14.3	25.8	1.9	.3	-8.8
1330	255	363	81.6	7.2	23.2	14.4	25.8	1.9	.3	-8.9
1400	248	351	82.1	7.2	23.2	14.5	25.8	1.9	.3	-9.0
1430	242	338	82.6	7.2	23.2	14.6	25.8	1.9	.3	-9.1
1500	236	326	83.2	7.2	23.2	14.7	25.9	1.9	.3	-9.2
1530	230	313	83.7	7.2	23.2	14.8	25.9	1.9	.2	-9.3
1600	224	300	84.3	7.2	23.2	14.9	25.9	1.9	.2	-9.4
1630	218	287	84.8	7.2	23.2	15.0	25.9	2.0	.2	-9.5
1700	212	274	85.4	7.2	23.2	15.1	25.9	2.0	.2	-9.6
1730	206	260	86.0	7.2	23.2	15.2	25.9	2.0	.2	-9.7
1800	200	247	86.5	7.2	23.2	15.3	25.9	2.0	.2	-9.8
1830	194	234	87.1	7.2	23.2	15.4	26.0	2.0	.2	-9.9
1900	188	221	87.7	7.2	23.2	15.5	26.0	2.0	.2	-10.0
1930	182	207	88.2	7.2	23.2	15.6	26.0	2.0	.2	-10.1
2000	177	195	88.8	7.2	23.2	15.7	26.0	2.0	.2	-10.2
HOUR	Zi	Zicl	RelHum	WIND	Th	Qp	Thv	Dth	Dthv	Dqp

Fig. 3-6. List of Predicted Values-Clear Sky

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APPENDIX C:

TERMS USED IN THE DISCUSSION AND PROGRAM:

Cn2 ... Index of refraction structure function parameter
[m -2/3]

Extinction ... loss of EM/EO energy due to absorption/
scattering by species (molecules/aerosols) in the path.

Lifting Condensation Level ... Level at which a parcel will
reach saturation if cooled while undergoing lifting.

Mixed Layer ... That part of the boundary layer where
turbulent mixing has destroyed the gradients of
conservative quantities.

Mixing Ratio ... the ratio of the water-vapor density to the
density of the dry air.

Potential Temperature ... the temperature that an air parcel
would assume if its pressure were changed by a
dry-adiabatic process to some standard pressure.

Relative Humidity ... the ratio of vapor pressure to
saturation vapor pressure times 100. Vapor in
equilibrium with sea water is assumed to have a
relative humidity of 98 per cent.

Specific Humidity ... the ratio of water-vapor density to
total density and is usually designated by q.

Subsidence ... a sinking of air from high to low levels. The
causes of its occurrence are dynamic, such as the
frictional outflow of air near the surface associated

with high-pressure systems, the divergence of air from

near the surface high pressure centers, and the

divergence of air due to change in latitude as an air

mass moves from north to south. (conservation of

absolute vorticity)

Thermal Wind ... vector wind change with height due to

horizontal temperature gradient. This implies

advection above the inversion.

Conversion ... KNOTS = (m/s) * 1.94

$$1.94 = \frac{ft}{.3048m} * \frac{Nm}{6076.1ft} * \frac{3600sec}{Hour}$$

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5    !  ************************************************************
10   !  ***             FOR TIE TO IREPS DATA PREDICTION          ***
15   !  ***      LT DAVID A. BROWER, USN, NPS, MONTEREY, CA.      ***
20   !  ************************************************************
25   ! BASIC DAVIDSON MODEL  ´MIXED2´                       MARCH 30
30   ! REVISED CHRIS FAIRALL ENTRAINMENT COMPUTATION   11JAN82
31   ! NOW INCLUDING LONG AND SHORT WAVE RADIATION
       13JAN82
35     EXIT GRAPHICS !                         UPDATED:  19 MAR 82
40     GCLEAR
45     OPTION BASE 1
50     NORMAL
55     OFF ERROR
60     PRINTER IS 0
65     PRINT CHR$(27)&"&l32T"
70     PRINTER IS 16
75     Mass$=":T14"    ! CHANGE HERE FOR A NEW MASS STORAGE
80     GOTO 155
85     ! THE FIRST LINE FOR ´COM´ NEEDED ONLY FOR 2.0
90   ! COM Irprog$,Irdata$,Rev$,Date$,Prints$,Perforated,
       Date_wanted
95     COM Name$[24],Loc$[24],Time$[24],Type$[1],Height$[1],
        Evap$[1]
100    COM Wmo$(30)[11],Wmont$[5]
105    COM SHORT Presur(30),Temper(30),Relhum(30)
110    COM SHORT Height(30),Munits(30),Nunits(30)
115    COM SHORT Wind,Sea,Air,Relhm,Htzero,Przero,Nmax,Delta,
        Change,Recenv
120    COM SHORT Coml(32,4),Envsq(16),Syssq(32),Lossq(32)
125    COM Envnam$(16)[24],Sysnam$(32)[24],Losnam$(32)[24]
130  ! COM Overlay$[24],Option$[80]
135  ! COM Nrec,Unprotected
140  ! DIM Dummy$[160],Errm$[80]
145  ! DIM Dlabel$[80],Default$[80],Doptions$[80]
150  ! DIM Next_overlay$[24]
155    DIM Windin(10,2),Stick$(3),Frame_loc$[24],Frame_date$[
        24]
160    INTEGER J
165    DIM Pot_temp(30),Spec_hum(30),Zsnd(30),L$[160]
170    Julday=150
175    Lat=33
180    SHORT G(63,7)
185    RESTORE 190
190    READ Z,Zot,Kkk,Alpha_t,Deltim,Stick$(*) ! Alpha_t is
        the ratio of heat to
195    DATA 10,5E-5,.35,1.35,1800      !      momentum transfer
        at Psi=0 [from BULK]
200    DATA "Gradient above","Inversion jump","      well-
        mixed"
205    Wsl=Ws=-.003   !TO SET A TYPICAL DEFAULT
210  PRINT PAGE,"THIS IS ´MYREPS´ WHICH MODELS THE CHANGE
```

81   D- 1

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             IN THE MIXED LAYER"
215   PRINT TAB(18),"ABOVE THE SURFACE";              !
          REV:18NOV80
220 Start:   Tday$=Date$
225    IF (Tday$="") OR (Tday$=" ") THEN Tday$=" 6MAR82"
230    DISP CHR$(7);"ENTER Today's Date,  THEN press
          'CONT'";
235    INPUT Tday$
240    PRINT Tday$
245    GOSUB Ireps_data
250    ! MINIMUM FREQ TRAPPED IN HERTZ= 3.6033E11*d(-3/2)   d
          DUCT THICKNESS IN m.
255 Option: ! TO WORK WITH THE IREPS KEYS
260 Menu: PRINTER IS 16
265    Aa=0
270    PRINT USING "@,K,2/,K";"This is the DIRECTION MENU",
          "Select option below, ENTER NUMBER and PRESS
          'CONT'."
275    PRINT USING "#,2/,2(10X,K,2/)";"1  COMPUTE NEW
          LAYER(displayed as computed on CRT)","2  PLOT of
          LAYER CHANGES "
280   PRINT USING "3(10X,K,2/),K";"3  END 'MIXED2'
          Program","4  RETURN TO IREPS OPTION LIST PROGRAM (
          with IREPS driver in T15)","5  REVIEW/CHANGE MENU"
285    INPUT "Enter Option(1 to 5) then press CONT",Aa
290    IF NOT ((Aa=1) OR (Aa=2) OR (Aa=3) OR (Aa=4) OR (Aa=5)
          ) THEN Menu
295    IF Aa=4 THEN Menu     !       LOAD "IREPS:T15",Input
          !  PUT IN LATER
300    ON Aa GOTO Start_out,Picture,Bye,Menu,Revchange
          !Subsidence
305    GOTO Menu
310 Start_out: IF Flag_rev THEN Run
315 Start_out_again:  GOSUB Disp_data
320    GOSUB Jullat
325    GOSUB Enter_winds
330    GOSUB Subsidence
335    GOSUB Sea_temp
340    GOSUB Plt_struct
345    GOTO Run
350 Revchange:   PRINTER IS 16    !  TO ENTER ANY CHANGES
          OR REVIEW DATA
355    Rc$="0"
360 IF NOT Flag_data THEN Menu      !  RETURN TO DIRECTION
          MENU IF NO DATA SET
365 Flag_rev=1         ! TO FLAG A RUN THROUGH THE REVISION
          ROUTINE
370    PRINT USING "@,K,/";"This is the REVIEW/CHANGE MENU"
375    PRINT USING "#,/,4(10X,K,2/)";"1  LIST CURRENT
          INITIAL VALUES","2  CHANGE WIND","3  CHANGE
          SUBSIDENCE","4  CHANGE SEA SURFACE TEMPERATURE"
```

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380  PRINT USING "#,/,3(10X,K,2/)";"5  CHANGE JULIAN DAY
        or LATITUDE","6  REDIGITIZE VERTICAL STRUCTURE","7
        SELECT NEW DATA SET"
385    PRINT USING "10X,K";"8  RETURN TO DIRECTION MENU"
390    INPUT "Enter Option(1 to 8) then press CONT",Rc$
395    PRINT PAGE
400    IF (NUM(Rc$)<49) OR (NUM(Rc$)>56) OR (LEN(Rc$)<>1)
        THEN Revchange
405    IF VAL(Rc$)=7 THEN Start_out_again
410    IF VAL(Rc$)=8 THEN Menu
415    ON VAL(Rc$) GOSUB List_curr,Enter_winds,Subsidence,
        Sea_temp,Jullat,Plt_struct,Disp_data,Menu
420    GOTO Revchange
425 List_curr:    GOSUB Hard_output
430    IF Hd$="Y" THEN PRINTER IS 0
435    PRINT "THESE ARE THE LATEST VALUES FOR THE PREDICTION
        MODEL"
440    PRINT USING "/,K";"DATA SET: "&Loc$&"    "&Time$
445    PRINT USING "/K,X3D,2X9A,M2D,2/,K,M.5D,8X,K,2D";
        "DATE:"&Tday$&"        JULIAN DAY:",Julday,
        "LATITUDE:",Lat,"SUBSIDENCE:",Wsl,"SURFACE TEMP:",
        Sea
450    PRINT USING "/,K,/";"FORECAST WINDS FOR THE PERIOD [
        KNOTS]"
455    FOR Win=1 TO Wn
460    PRINT USING "ZZ,2A,2X,3D.D";Windin(Win,1)/2 MOD 24,
        "00",Windin(Win,2)*1.94
465    NEXT Win
470    IF Hd$="Y" THEN RETURN
475    DISP "PRESS CONT WHEN READY"
480    PAUSE
485    RETURN
490 Jullat:  PRINT USING "@,K,/,K,3D";"FOR DATA SET: "&Loc$&
        "    "&Time$,"CURRENT JULIAN DAY: ",Julday
495    INPUT "ENTER NEW JULIAN DAY(1 TO 366), PRESS CONT
        ",Julday
500    PRINT USING "@,K,M2D.4D";"CURRENT LATITUDE IS :";Lat
505    INPUT "ENTER LATITUDE(DEG  -90 TO 90), PRESS CONT
        ",Lat
510    RETURN
515 Enter_winds: PRINTER IS 16!KNOTS = METERS *1.94 |
        1.94= ft  *  Nm  *3600sec
520    MAT Windin=ZER              !          SECOND       |
        .3048m 6076.1ft  Hr
525    ON ERROR GOTO 530
530    PRINT USING "@,K, 4X ,K";Loc$,Time$
535    INPUT "ENTER THE BEGINNING TIME ( TO NEAREST HOUR
        e.g. 0600)",Inll$
540    IF (LEN(Inll$)<>4) OR (VAL(Inll$[1;2])>24) THEN 530
545    IF Inll$[1;2]="00" THEN Inll$[1;2]="24"
550    REDIM G(VAL(Inll$[1;2])*2-1:VAL(Inll$[1;2])*2+61,7)
```

```
555    OFF ERROR
560    Wn=1
565    Windin(1,1)=Nr11=VAL(Inll$[1;2])*2   ! PUT PERIOD IN
          WIND HOLDING ARRAY
570    Q$="Y"
575    Wind_begin1=wind                         ! USE THE VALUE
          FROM IREPS
580    PRINT USING "@,KX,3D.D,2XK";"WIND FROM  IREPS  IS ";
          Wind*1.94,"KNOTS"
585    INPUT "IS THIS WIND OKAY?  PRESS CONT TO USE THIS
          WIND (Y/N)",Q$
590    IF Q$[1;1]="Y" THEN 610
595    DISP "ENTER BEGINNING WIND SPEED  [KNOTS]  at time ";
          Inll$;
600    INPUT Wind_begin1
605    Wind_begin1=Wind_begin1/1.94             !CHANGE INTO
          METERS PER SECOND
610    PRINT USING "@,K,4A,K,3D.D,6A";"AT BEGINNING TIME: ";
          Inll$[1,2]&"00";" THE WIND SPEED IS ";Wind_begin1*
          1.94;" KNOTS"
615    PRINT USING "2/,K,2(/,K)";"Enter the hour and minutes
          of each prediction, then the wind.","Separate time
          from wind by a comma","DISPLAYED winds in KNOTS"
620    PRINT USING "/,K,2Z,16A,/,K";"The last period is 30
          hours after the beginning (i.e. ",(Nr11/2+30) MOD
          24,"00 the next day)","PERIOD  TIME   WIND"
625    PRINT USING "X2D,5X,4A,5X,2D.D";1,Inll$[1;4],
          Wind_begin1*1.94
630    G(Nr11+60,3)=Windin(1,2)=MAX(Wind_begin1,.0001)
635    Q$="Y"
640    FOR Win=2 TO 10    ! MAX OF 10 WIND INPUTS....FIRST
          ONE FROM ABOVE
645 One_wind: LINPUT "hhmm,wW   FROM THE FORECAST,
       ENTER TIME,WIND(KNOTS) [END when done]",Inl2$
650    IF (Inl2$[1;2]="99") OR (UPC$(Inl2$[1;1])="E") THEN
          Print_wind
655    IF (LEN(Inl2$)<5) OR (Inl2$="") THEN 645
660   IF NOT (Inl2$[5;1]=",") OR (VAL(Inl2$[1;2])>24) OR (
          Inl2$[6;1]="") THEN 645
665    PRINT USING "X2D,5X,4A,5X,K";Win,Inl2$[1;4],Inl2$[6]
670    Windin(Win,1)=VAL(Inl2$[1;2])*2     !  TIMES 2 TO GET
          # OF PERIOD
675    G(Nr11+60,3)=Windin(Win,2)=MAX(VAL(Inl2$[6])/1.94,
          .0001)
680    IF UPC$(Q$[1,1])="N" THEN RETURN
685    Wn=Win                                 ! COUNT THE TOTAL
          WINDS ENTERED
690    NEXT Win
695 Print_wind: Q$="Y" ! HERE TO PUT WIND IN 'G' ARRAY
700    PRINT PAGE,"WINDS THROUGH FORECAST PERIOD"
705    FOR Win=1 TO Wn
```

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```
710     PRINT USING "5X,2D,2X,ZZ,2A,2X,3D.D";Win,windin(Win,1)/
           2 MOD 24,"00",Windin(Win,2)*1.94
715     NEXT Win
720     Q$="Y"
725     INPUT "DO THESE WINDS LOOK OKAY (Y/N)?",Q$
730     IF UPC$(Q$[1,1])="Y" THEN 745
735     IF UPC$(Q$[1,1])="N" THEN Fixwind
740     GOTO Print_wind
745     G(Nr11-1,3)=G(Nr11,3)=Windin(1,2)
750     win1=0
755     Iday1=Nr11
760     FOR Win=2 TO Wn
765     IF Windin(Win,1)<Iday1 THEN win1=win1+48
770     G(MIN(Windin(Win,1)+win1,Nr11+61),3)=Windin(Win,2)
           !TO PREVENT TIME BEYOND
775     Iday1=Windin(Win,1)
780     G(Nr11+60,3)=Windin(Win,2)   ! AUTOMATIC PUT THE LAST
           WIND INTO END PERIOD
785     NEXT Win
790     RETURN
795 Fixwind:   INPUT "ENTER PERIOD NUMBER TO CHANGE",Win
800     IF Win>Wn THEN Fixwind
805     GOSUB One_wind
810     GOTO Print_wind
815 Subsidence:  ! COME HERE NORMALLY OR FOR RETRY WITH
           DIFFERENT SUBSIDENCE
820     FIXED 4
825     DISP "ENTER  SUBSIDENCE (m/sec) [Prior value=";Ws1;"],
           or CONT to use same value";CHR$(7);
830     INPUT Ws1
835     RETURN
840 Sea_temp:  PRINT "PRESENT VALUE OF SEA SURFACE
           TEMPERATRURE IS ";Sea
845     INPUT "ENTER THE SEA SURFACE TEMP IN 'C or just
           CONT for same value",Sea
850     Tsfc=Sea+273.16
855     RETURN
860 Assig_error:  IF ERRN=80 THEN No_data
865     DISP "ERROR #";ERRN;" in line ";ERRL;"      PRESS
           CONT when ready",CHR$(7)
870     PAUSE
875     GOTO Start
880 No_data:  PRINT PAGE,"DATA FILE NOT AVAILABLE IN LEFT
           TAPE DRIVE.",LIN(2),"EITHER NO TAPE or NOT A DATA
           TAPE.",LIN(2)
885     PRINT "INSERT OR MAKE OTHER CHOICE",LIN(2),"PRESS
           CONT  TO TRY AGAIN WITH DATA TAPE IN LEFT SIDE
           TAPE DRIVE"
890     BEEP
895     PAUSE
900 Ireps_data:     ! TO DISPLAY THE FILE NAMES OF DATA ON
```

```
          IREPS DATA TAPE
905     ON ERROR GOTO Assig_error
910     ASSIGN #5 TO "ENVIR"&Mass$,Ier
915     IF Ier THEN No_data
920     ASSIGN #6 TO "SEQNCE"&Mass$,Ier
925     IF Ier THEN No_data
930     READ #6;Envsq(*),Syssq(*),Lossq(*)
935     ON END #5 GOTO All_out
940       FOR I=1 TO 16
945       READ #5,I;Envnam$(I)
950       NEXT I
955     GOTO All_full
960 All_out:      FOR J=I TO 16   ! I HAS BEEN INCREMENTED 1
        ABOVE LAST READ I
965     Envsq(J)=0
970     NEXT J
975 All_full: RETURN   !  ARRAY FILLED WITH NAMES and
        REMAINDER WITH 0's


980 Disp_data:  PRINTER IS 16 ! TO PUT THE DATA SETS UP FOR
        CHOICE
985     PRINT USING "@,K,5X,K,2/,5X,2D,2X,K";CHR$(7),
        "EXISTING ENVIRONMENTAL DATA SETS ON IREPS TAPE:",
        0,"NEW or RETURN TO MENU SELECTION"
990     FOR I=1 TO 16
995     Rec=Envsq(I)
1000    IF NOT Rec THEN Pick_data
1005    PRINT USING "5X,DD,2X,K";I,Envnam$(Rec)[1,23]
1010    NEXT I
1015    I=17
1020  Pick_data:    Nrec=I-1
1025    OFF ERROR
1030    IF Nrec<=0 THEN Menu
1035    INPUT "ENTER THE NUMBER OF THE DATA SET DESIRED",
        Dummy
1040    IF Dummy=0 THEN Menu
1045    IF NOT ((Dummy>=1) AND (Dummy<=Nrec)) THEN Disp_data
1050    Rec=Dummy
1055    DISP "PROGRAM IS WORKING RECORD NUMBER ",Rec,";",
        TRIM$(Envnam$(Envsq(Rec))[1,23])," IS BEING READ"
1060    READ #5,Envsq(Rec);Name$,Loc$,Time$,Type$,Hight$,
        Evap$,Wmo$(*),Wmonth$
1065    READ #5;Presur(*),Temper(*),Relnum(*),Height(*),
        Munits(*),Nunits(*)
1070    READ #5;Wind,Sea,Air,Relhm,Htzero,Przero,Nmax,Delta,
        Change
1075 FOR I=1 TO Nmax-1
1080 IF (Presur(I)=0) OR (Height(Nmax-I+1)>10000) OR (I=21)
        THEN GOTO 1110
1085      Spec_hum(I)=FNQvalue(Temper(I),Relnum(I))
```

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```
1090        Pot_temp(I)=Temper(I)+.0098*Height(Nmax-I)
1095        Zsnd(I)=Height(Nmax-I)*1
1100        Digit_top=I
1105 NEXT I
1110   Press=Przero
1115   IF Press=0 THEN Press=1012   !DEFAULT TO STANDARD IF
        NO OTHER VALUE
1120   MAT G=ZER
1125 Flag_rev=0        ! TO FLAG A NEW DATA SET
1130 Flag_data=1       ! TO FLAG A DATA SET CHOSEN
1135   RETURN              ! GET THE WINDS THEN DO VERTICAL
        STRUCTURE


1140 Plt_struct: !
1145   PLOTTER IS 13,"GRAPHICS"
1150   GRAPHICS                          !**********LABEL
        VERTICAL PLOT**********
1155   PEN 1
1160   LINE TYPE 1
1165   SCALE -3,30,-200,2400
1170   CLIP 0,30,0,2400
1175   AXES 1,500,0,0,5,2
1180   UNCLIP
1185   LORG 2
1190   MOVE -3,-65
1195   LABEL USING "K";"SPEC. HUM.   Q"
1200   MOVE -3,-130
1205   LABEL USING "K";"POT. TEMP.   'C"
1210   LORG 8
1215   MOVE 30,2285                      ! ************DRAW WIND ON
        PLOT*********
1220   LABEL USING "8AX";"FORECAST"
1225   MOVE 30,2225
1230   LABEL USING "K";"TIME    WIND"
1235   FOR L=1 TO Wn
1240   MOVE 30,2200-L*80
1245   BEEP
1250   LABEL USING "ZZ,2A,2X,3D.D";Windin(L,1)/2 MOD 24,"00",
        Windin(L,2)*1.94
1255   NEXT L
1260   LORG 5
1265   FOR L1=1 TO 2
1270 FOR L=5 TO 25 STEP 5
1275   MOVE L,-65*L1
1280        LABEL USING "M3D";L*L1-(L1-1)*10
1285   NEXT L
1290   NEXT L1
1295   FOR L=500 TO 2000 STEP 500        ! ********LABEL SIDE
        NUMBERS*******
```

```
1300   MOVE -1,L
1305   LABEL USING "4D";L
1310   NEXT L
1315   DEG
1320   LDIR 90
1325   LORG 2
1330   MOVE -2.5,0
1335   LABEL USING "K";Loc$&"     "&Time$&"     "&"HEIGHT (meters)
           "&Tday$
1340   LDIR -30
1345   MOVE 3,2400
1350   LABEL USING "XK";"SPECIFIC HUMIDITY Q"
1355   LORG 8
1360   LDIR 30
1365   MOVE 22,2400
1370   LABEL USING "K";"POTENTIAL TEMP  O"
1375   MOVE 22,2400
1380   LABEL USING "A";"-"
1385   LDIR 0
1390   LORG 5
1395   MOVE 25,500                          !**********LABEL
           LEGEND**********
1400   LABEL USING "15A";"   √_Q  |Theta_/"
1405   LORG 8
1410   MOVE 30,750
1415   LABEL USING "10A,2X,MZ.4D";"Subsidence",Wsl
1420   MOVE 25,600
1425   LABEL USING "18A";"MIXED LAYER HEIGHT"
1430   FOR L=1 TO 3
1435   MOVE 25,500-L*100
1440   LABEL USING "14A,7X";Stick$(L)
1445   NEXT L
1450   SCALE -16,50,-200,2400
1455   MOVE Pot_temp(1),Height(Nmax)  !**********DRAW THETA *
           *********
1460     FOR L=2 TO MIN(Nmax-1,Digit_top)
1465     DRAW Pot_temp(L),Height(Nmax-L)
1470     NEXT L
1475   Zi=Zi3
1480   POINTER Pot_temp(2),Height(Nmax-3),1   !  FULL SCREEN
           CURSOR
1485   BEEP                             !**********GET THETA***
           *******
1490   DIGITIZE Mixtemp,Zi
1495   MOVE 40,600
1500   LORG 2
1505   LABEL USING "X4D,2A";Zi;"m."
1510   MOVE 40,200
1515   LABEL USING "XM2D.D";Mixtemp
1520   BEEP
1525   POINTER Mixtemp+5,Zi,2
```

```
1530    DIGITIZE Top_inv_temp,Mmm
1535    MOVE 40,300
1540    LABEL USING "X2D.D";Top_inv_temp-Mixtemp
1545    POINTER Top_inv_temp+10,2350,2
1550    BEEP
1555    DIGITIZE Top_temp,Top_temp_alt
1560    MOVE 40,400
1565    LABEL USING "X2.4D";(Top_temp-Top_inv_temp)/(
           Top_temp_alt-Zi) !



1570    LINE TYPE 3          !**********DRAW STICK THETA********
           **
1575     MOVE Mixtemp,0
1580     DRAW Mixtemp,Zi
1585     DRAW Top_inv_temp,Zi
1590     DRAW Top_temp,Top_temp_alt
1595    LINE TYPE 1
1600     LORG 8  !WRITE UNDER 'Q' SIDE
1605    SCALE -3,30,-200,2400
1610     BEEP
1615    LINE TYPE 8
1620      MOVE Spec_hum(1),Height(Nmax) !**********DRAW Q ****
           ******
1625      FOR L=2 TO MIN(Nmax-1,Digit_top)
1630      DRAW Spec_hum(L),Height(Nmax-L)
1635      NEXT L
1640      LINE TYPE 1
1645     POINTER Spec_hum(2),Zi,1
1650    DIGITIZE Mixq,Mmm     ! USING THIS TERM SO SCALE STAYS
           THE SAME
1655     MOVE 25,200
1660     LABEL USING "M2D.2DX";Mixq
1665     POINTER Mixq/2,Zi,2
1670     BEEP
1675     DIGITIZE Top_inv_q,Mmm    ! USE FOR SAME SCALE FACTOR
           GRAPHICS
1680     MOVE 25,300
1685     LABEL USING "M2D.2DX";Top_inv_q-Mixq
1690     POINTER Top_inv_q/2,2350,2
1695     BEEP
1700     DIGITIZE Top_q,Top_q_alt
1705     MOVE 25,400
1710     LABEL USING "M.4DX";(Top_q-Top_inv_q)/(Top_q_alt-Zi)
1715     Zi3=Zi
1720     LINE TYPE 4             !**********DRAW STICK Q *******
           ***
1725     MOVE Mixq,0
1730     DRAW Mixq,Zi
1735     DRAW Top_inv_q,Zi
```

```
1740    DRAW Top_q,Top_q_alt
1745    LINE TYPE 1
1750    SCALE -16,50,-200,2400
1755    MOVE 40,100
1760    LORG 5 !*********  FOR DECISION OF A GOOD FIT OR
        NOT**********
1765    LABEL USING "17A";" OKAY <-|-> AGAIN"
1770    POINTER 40,100,2
1775    BEEP
1780    DIGITIZE D,Mmm
1785    IF D=40 THEN 1770
1790    IF D>40 THEN Plt_struct
1795    PRINTER IS 16
1800    PRINT PAGE
1805    MOVE 40,100
1810    DISP "CLEARING PICTURE"
1815    EXIT GRAPHICS
1820       PEN -1
1825    LABEL USING "17A";" OKAY <-|-> AGAIN"
1830    GOSUB Hard_output
1835    IF Hd$="N" THEN 1885
1840   PRINTER IS 0
1845 PRINT USING "  1X,K,2(6X,K),/";"ENVIRON. DATA LIST,
        FROM MIXED2",Loc$,Time$
1850 PRINT USING "3(10A,X4D.D,9X18A,M3D.D,/)";"WIND",Wind,
        "AIR TEMP",Air,"SEA TEMP",Sea,"REL HUM",Relhm,"SFC
        PRESS",Przero,"IREPS EVAP DUCT HT",Delta
1855   PRINT "LEVEL  PRESS    TEMP  RH %    METERS   M UNITS
        POTENT TEMP  SPEC HUM"
1860 FOR I=1 TO MIN(18,Digit_top)
1865 PRINT USING "3D,3X,4D.D,2X,M2D.D,X,3D.D,X,6D.D,4X,4D,2(
        6X,M3D.D)";I,Presur(I),Temper(I),Relhum(I),Height(
        Nmax-I),Munits(Nmax-I),Pot_temp(I),Spec_hum(I)
1870 NEXT I
1875    DUMP GRAPHICS
1880    PRINT USING "@"
1885    PRINTER IS 16
1890    EXIT GRAPHICS
1895    RETURN
1900 Run: T10=Mixtemp   !**********PREP DATA FOR RUN WITH
        IREPS**********
1905         Zi=Zi3
1910    Qp=Mixq
1915    Dqp=Top_inv_q-Mixq
1920    Dqdzu=(Top_q-Top_inv_q)/(Top_q_alt-Zi)
1925    Dth=Top_inv_temp-Mixtemp
1930    Dtdzu=(Top_temp-Top_inv_temp)/(Top_temp_alt-Zi)
1935    Ws=Wsl
1940    Frame_loc$=Loc$
1945    Frame_date$=Time$
1950    EXIT GRAPHICS
```

```
1955     CALL Sky2(Zi,Nmax*1,Pot_temp(*),Zsnd(*),Spec_hum(*),
           Tsky,Ftop)
1960  Mhr=60                   !  TO SET MHR= NUMBER OF HALF HOUR
         PERIODS
1965  OFF ERROR
1970 PRINT PAGE,TAB(9),"THIS IS ´MIXED2´, MODELING THE
         CHANGE IN THE MIXED LAYER"
1975 PRINT TAB(10),"ABOVE THE OCEAN SURFACE. Today is "&
         Tday$
1980  Numhr=Nrl1+Mhr
1985  PRINTER IS 16
1990  PRINT USING "/,15X,K,/,20X,4Z,2XK,/19X,4D,K,/";"DATA
         PARAMETERS CHOSEN",Nrl1/2 MOD 24*100,"BEGINNING
         TIME",Zi,"m  CAPPING INVERSION HEIGHT"
1995  Vdt=0
2000 ! INPUT "ENTER A VALUE FOR ´Vdte´ (´C/12hr) , or PRESS
         CONT FOR DEFAULT TO 0  ?",Vdt
2005  Vdte=Vdt/24
2010 ! PRINT "THE VALUE FOR ´Vdte´ IS ";Vdt;" ´C/12hr   or ";
         Vdte;" ´C per TIME STEP"
2015  Th=T10+273.16
2020  J=Nrl1-1
2025  G(Nrl1-1,1)=Zi
2030  GOSUB Bulk
2035  Nrl=Nrl1
2040  I=Nrl                    ! FIND FIRST INPUT DATA LINE
2045  I=I+1                    ! INCREMENT TO NEXT LINE
2050   IF G(I,3)=0 THEN 2045! IF NO DATA, INCREMENT
2055  Nd=I-Nrl                 ! FIGURE TIME SPREAD
2060    X5=(G(I,3)-G(Nrl,3))/Nd   !U10
2065  FOR J=1 TO Nd-1         ! STEP THROUGH EMPTY POINTS
2070    G(J+Nrl,3)=G(Nrl,3)+X5*J
2075  NEXT J                               ! DQDZU= Specific hum
         gradient above inv.
2080  Nrl=I                                ! DTH= Potential
         temperature jump
2085  IF I<Numhr THEN 2045                 ! DTDZU= Temp
         gradient above inversion
2090    T=Th-.0098*Zi*.5-273.16            ! DQW= Specific
           humidity jump
2095    Lcp=(596.73-.601*T)/.24            ! TH= Well mixed
           potential temperature
2100    Tt=T-.0098*Zi*.5+273.16            ! Qp= Well mixed
           specific humidity
2105    Te=Th*(1+Lcp/Tt*Qp/1000)           ! ZI= Inversion height
2110    Dte=Dth+Th/Tt*Lcp*Dqp/1000         ! DELTIM=Time step
           between solutions
2115    Dtedzu=Dtdzu+Th/Tt*Lcp*Dqdzu/1000
2120    Dqw=Dqp/1000
2125    Qw=Qp/1000
2130    Aws=Ws/Zi                ! AVERAGE Ws THRU THE MIXED
```

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```
                LAYER
2135     Zws=Zi                      ! REMEMBER HEIGHT OF
                BEGINNING Ws
2140 PLOTTER IS 13,"GRAPHICS"
2145 SCALE Nrll-20,Nrll+80,-100,2000
2150 CLIP Nrll,Nrll+61,0,1200
2155 AXES 4,200,Nrll,0,3,5
2160 FRAME
2165 GRAPHICS  !




2170    Run$="*"
2175 Looper:  FOR J=Nrll TO Nrll+Mhr
2180    Zil=Zi              ! HOLD ONTO PREVIOUS HEIGHT
2185    PLOT J,Zi           ! FOR THE QUICK PLOT
2190  T10=Th-273.16    ! T10 CARRIED BACK FROM 'Bulk' AS Th
2195     Q10=Qp             ! NEW VALUE OF Qp
2200    FIXED 2
2205   D tedzu=Dtdzu+Th/Tt*Lcp*Dqdzu/1000
2210    IF J>Nrll+56 THEN Run$="!"
2215      DISP "PERIOD BEGIN:";TAB(14+(J-Nrll)/2);Run$;TAB(
            45);":END     Layer at";G(J-1,1)
2220    O2=Dqdzu/1000                        ! TO CHANGE G/KG TO G/
        G
2225    Timesec=J*1800
2230    CALL Zenith(Timesec,Julday,Lat,Theta)
2235 CALL M2(T10,Q10,Zlcl,Zi,Ustar,Tstar,Qstar,Tstv,Ws,Delr,
      O2,Dte,Dqw,Dhdt,Ddtedt,Ddqwdt,Dtedt,Dqwdt,Wtv,
      Dtedzu,Tsfc,Theta,Tsky)
2240    G(J,2)=Zlcl
2245    G(J,1)=Zi=Zi+Dhdt*Deltim
2250      Qw=Qw+Dqwdt*Deltim               ! GRAMS PER GRAM
2255    G(J,4)=Q10=Qp=Qw*1000             ! GRAMS PER KILOGRAM
2260      Te=Te+Dtedt*Deltim              ! EQUIVALENT POTENTIAL
            TEMP
2265      Dqw=Dqw+Ddqwdt*Deltim           ! GRAMS PER GRAM
2270    G(J,6)=Dqp=Dqw*1000              ! GRAMS PER KILOGRAM
2275      Dte=Dte+Ddtedt*Deltim+Vdte ! ADDING THERMAL WIND
2280      Ws=Aws*Zi                       ! RESETTING LAYER
            SUBSIDENCE
2285      Zws=Zws+Aws*Zws*Deltim
2290      Tt=Tt-.0098*(Zi-Zil)            ! Tt IN KELVIN
2295      T=Tt+.0098*Zi*.5-273.2
2300      Lcp=(596.73-.601*T)/.24
2305    G(J,5)=Th=Te/(1+Lcp*Qw/Tt)     ! Th in KELVIN
2310    G(J,7)=Dth=Dte-Th/Tt*Lcp*Dqw
2315 ! G(J,2)=MIN(100,FNRelhum(Qp,Th))      ! FIGURED AT 10
        METER LEVEL
```

```
2320      GOSUB Bulk  ! COMPUTE STAR VALUES FOR NEXT TIME
          PERIOD

2325      NEXT J
2330      EXIT GRAPHICS
2335      GOTO Menu  !


2340 Bulk: ! TO COMPUTE THE NEXT SET OF VALUES FOR U*,T*,Q*,
      T*v
2345    U10=MAX(.2,G(J,3)) ! WIND CHANGES THROUGH THE PERIOD
2350    IF U10>=2.2 THEN Cdn=.789*U10^.259/1000 ! FIGURE
        DRAG FROM WIND CURVE FIT
2355    IF U10<2.2 THEN Cdn=U10^(-.15)*1.08/1000   ![ DAB
        SEP 80]
2360    RAD
2365    Tdelta=Th-Tsfc      ! DIFFERNCE IN TEMPERATURE AND Q-
        value
2370    Qdelta=Qp-FNQvalue(Sea,98) ! FROM 10meters TO THE
        SURFACE
2375    Zo=Z*EXP(-Kkk/SQR(Cdn))
2380    Ctn_sqrt=Alpha_t*Kkk/LOG(Z/Zot)
2385    S1=S=So=Kkk*9.8*Z/Th*(Ctn_sqrt/Cdn)*(Tdelta+.00061*
        Th*Qdelta)/U10^2
2390      IF So<0 THEN 2450
2395      IF So<2 THEN GOTO 2420
2400         S=10
2405         Psi1=-47
2410         Psi2=-64
2415        GOTO Stars
2420         Psi1=-S*4.7
2425         Psi2=-S*6.4
2430      S=So*Alpha_t/Kkk*((Kkk-SQR(Cdn)*Psi1)^2/(Alpha_t*
          Kkk-Ctn_sqrt*Psi2))
2435    IF ABS(S-S1)<.001 THEN Stars
2440       S1=S
2445    GOTO 2420
2450         X1=(1-15*S)^.25
2455         X2=(1-9*S)^.5
2460         Psi2=2*LOG((1+X2)/2)
2465         Psi1=2*LOG((1+X1)/2)+LOG((1+X1^2)/2)-2*ATN(X1)+
             PI/2
2470      S=So*Alpha_t/Kkk*((Kkk-SQR(Cdn)*Psi1)^2/(Alpha_t*
          Kkk-Ctn_sqrt*Psi2))
2475    IF ABS(S-S1)<.001 THEN Stars
2480       S1=S
2485    GOTO 2450
2490 Stars:     Mult=Alpha_t*Kkk/(LOG(Z/Zot)-Psi2)
2495            Ustar=Kkk*U10/(LOG(Z/Zo)-Psi1)
2500            Tstar=Tdelta*Mult
2505            Qstar=Qdelta*Mult
```

```
2510            Tstv=Tstar+.61*Qstar*Th/1000
2515    RETURN ! VALUES BACK FOR BEGINNING AND FOR DURING
          RUN


2520  Picture: EXIT GRAPHICS
2525   IF NOT Flag_data THEN Menu
2530     PRINTER IS 16
2535     OFF ERROR
2540     PRINT USING "3,K,2/,3(10X,K,2/)";"TYPE OF PLOT:","1
          PLOT THE ´BIG PICTURE´"," 2  PLOT OF ´Q´, ´THETA´
          AND JUMPS","3  LIST OF THE PLOTTED VALUES"
2545     PRINT "          4  RETURN TO DIRECTION MENU"
2550     ON ERROR GOTO Picture
2555     INPUT "ENTER MODE of output?",Vss
2560     PRINT PAGE,"PRESS  CONT wnen picture is done",LIN(
          2),"    [ k3  TO DISPLAY GRAPHICS]"
2565     IF Vss=1 THEN CALL Frame(G(*),Nr11,Tday$,Dqdzu,
          Dtdzu,Press,Frame_loc$,Frame_date$,Mhr)
2570     ON Vss GOTO Picture,Mix_plot,Gval,Menu
2575   ! ON Vss GOTO Picture,Picture,Gval,Menu
2580     GOTO Picture
2585  Hard_output: Hd$="N"
2590     INPUT "DO YOU WANT HARD COPY OUTPUT (N/Y)",Hd$
2595     Hd$=UPC$(Hd$[1,1])
2600     IF (Hd$="Y") OR (Hd$="N") THEN RETURN
2605     GOTO Hard_output !


2610  Gval:! PRINT OUT THE VALUES FOR THE ENTIRE PERIOD
2615   GOSUB Hard_output
2620   OFF ERROR
2625     IF Hd$="Y" THEN PRINTER IS 0
2630  L$="This is a list of plotted values. "&Loc$&"    "&
      Time$&"   "&Tday$
2635    PRINT L$[1;78],LIN(1)
2640  PRINT "HOUR   Zi   Zlcl RelHum  WIND   Th      Qp
      Thv    Dth   Dthv   Dqp"
2645     FOR G1=Nr11 TO Nr11+Mhr
2650     G2=INT(G1 MOD 48/2)*100+FRACT(G1 MOD 48/2)*60
2655   G3=G(G1,5)*(1+.00061*G(G1,4))! Thv
2660   G4=G(G1,7)+.00061*G(G1,5)*G(G1,6)! Dthv
2665   G5=FNRelhum((G(G1,4)),(G(G1,5)))
2670     PRINT USING "4Z2X,2(4DX),2(M3D.DX),6(3D.D2X)";G2,G(
          G1,1),G(G1,2),G5,G(G1,3),G(G1,5)-273.16,G(G1,4),
          G3-273.16,G(G1,7),G4,G(G1,6)
2675     NEXT G1
2680     PRINT "HOUR   Zi   Zlcl RelHum  WIND   Th      Qp
      Thv    Dth   Dthv   Dqp"
2685     DISP "PAUSING FOR 2 SECONDS THEN RETURNING TO THE
          START"
```

```
2690    IF Hd$="N" THEN WAIT 2000
2695      ! WHEN YOU ARE READY, JUST PRESS CONT
2700      PRINT PAGE
2705      GOTO Picture!


2710 Mix_plot:! BEGIN PLOT OF Qp,Dqp,Th,Dth,RH
2715    OFF ERROR
2720    PLOTTER IS 13,"GRAPHICS"
2725    GRAPHICS
2730    FRAME
2735    SCALE Nr11-5,Nr11+60,-8,8
2740    CLIP Nr11,Nr11+60,-8,8
2745    AXES 2,1,Nr11,0,3,1
2750    LORG 2
2755    MOVE Nr11,7.5
2760    LABEL USING "K";" POTENTIAL TEMPERATURE [´C]"
2765    MOVE Nr11,7
2770    LABEL USING "K";" POT TEMP jump - - -"
2775    MOVE Nr11,-.5
2780    LABEL USING "K";" SPECIFIC HUMIDITY [g/kg]"
2785    MOVE Nr11,-1
2790    LABEL USING "K";" SPEC HUM jump - - -"
2795    FOR K=0 TO 2 STEP 2
2800        LORG 3
2805      SCALE Nr11-5,Nr11+60,INT(G(Nr11,4+K))-4,INT(G(Nr11,
          4+K))+12
2810      FOR I=0 TO 1
2815       P=-2
2820       LINE TYPE 1
2825       FOR L=INT(G(Nr11,4+K+I)-3-273.16*((K=0) AND (I=1)))
           TO INT(G(Nr11,4+K+I)+3-273.16*((K=0) AND (I=1)))
2830        MOVE Nr11+K*30,L
2835        LABEL USING "MDDX";L
2840       NEXT L
2845       LINE TYPE 1+3*(K=2)
2850       FOR J=Nr11 TO Nr11+60
2855       PLOT J,G(J,4+I+K)-((I=1) AND (K=0))*273.16,P
2860       P=-1
2865       NEXT J
2870      SCALE Nr11-5,Nr11+60,INT(G(Nr11,5+K)-12-273.16*(K=0)
          ),INT(G(Nr11,5+K)+4-273.16*(K=0))
2875     NEXT I
2880    LINE TYPE 4
2885    NEXT K
2890    GOSUB Hard_output
2895    IF Hd$="Y" THEN PRINTER IS 0
2900    PRINT USING "K";"TEMPERATURE and HUMIDITY for "&Loc$&
        "  "&Time$
2905    IF Hd$="Y" THEN DUMP GRAPHICS
2910    GCLEAR
```

```
2915    SCALE Nr11-5,Nr11+60,-20,120
2920    LINE TYPE 1
2925    CLIP Nr11-5,Nr11+60,40,100
2930    FRAME
2935    AXES 2,10,Nr11,40,3,2
2940    MOVE Nr11,FNRelhum((G(Nr11,4)),(G(Nr11,5)))
2945    FOR I=Nr11+1 TO Nr11+60
2950    DRAW I,FNRelhum((G(I,4)),(G(I,5)))
2955    NEXT I
2960    LORG 2
2965    MOVE Nr11,105
2970    LABEL USING "K";" RELATIVE HUMIDITY at 10 meter
           level"
2975    LORG 7
2980    MOVE Nr11,80
2985    LABEL USING "3AX";"80%"
2990    MOVE Nr11,60
2995    LABEL USING "3AX";"60%"
3000    FOR Cc=Nr11 TO Nr11+60 STEP 12
3005    MOVE Cc,110
3010    LABEL USING "ZZ,ZZ";INT(Cc/2) MOD 24,FRACT(Cc/2)*60
3015    NEXT Cc
3020  IF Hd$="Y" THEN DUMP GRAPHICS 40,115
3025    BEEP
3030    IF Hd$="N" THEN PAUSE
3035  EXIT GRAPHICS
3040    IF Hd$="N" THEN Picture
3045    PRINTER IS 0
3050    PRINT USING "2(/,9XK)";"30-HOUR PREDICTION OF
           POTENTIAL TEMPERATURE AND HUMIDITY","The well-
           mixed value scale is along the left, the ´jump´
           value"
3055    PRINT USING "8XK,@";"scale is along the right.  The
           third frame is Relative Humidity."
3060    GOTO Picture!


3065 Bye:  PRINT PAGE,"THIS PROGRAM IS ENDING AND REWINDING
           THE TAPE"
3070  PRINT LIN(1),"REMOVE TAPE BY PRESSING THE EJECT BAR"
3075  ON ERROR GOTO 3085
3080  REWIND ":T15"
3085  ON ERROR GOTO 3095
3090  REWIND ":T14"
3095  PRINT LIN(6),TAB(36),"Good bye"
3100  BEEP
3105  OFF ERROR
3110 En:  END!
```

```
3115 SUB M2(T10,Q10,Zlcl,Zi,Ust,Tst,Qst,Tstv,Ws,Delr,Dqdzu,
         Dte,Dqw,Dhdt,Ddtedt,Ddqwdt,Dtedt,Dqwdt,Wtv,Dtedzu,
         Tsfc,Theta,Tsky)
3120    Tt=T10+273.2-.0098*Zi/2
3125    Thet=(Tt+Zi*.0098)/Tt
3130    Cl=(596.73-.601*(Tt-273.2))/(.24*Tt)   ! Cl=L/(Cp*T)
3135    Wt=-Tst*Ust
3140    Wtv=-Tstv*Ust
3145    Wq=-Qst*Ust/1000
3150    Wte=Wt+Thet*Cl*Tt*Wq
3155    Te=T10+2.43*Q10
3160 CALL Parcel0(Te,Q10,Zi,Rh,Thr,Qv,Ql,Zlcl)
3165    Qs=Qv/1000*Rh/100
3170    Qliq=Ql/1000
3175    ! WAIT 1000
3180 CALL We2(Zi,Zlcl,Dte,Dqw,Qs,Thr,Qliq,T10,Tsfc,Ust,Tst,
         Qst,Tstv,We2,Delr,Tsky)      ! NEED TO CALL PARCEL
         FIRST
3185    CALL Shrtwv(Theta,Ql,Zlcl,Zi,Q10,Dtemp)
3190    We=We2
3195    Dhdt=We+Ws       ! Rate of change of mixed layer depth,
         Ws is subsidence
3200    Ddtedt=Dtedzu*We+(-We*Dte-Wte+Thet*Delr)/Zi-Dtemp
3205    Ddqwdt=Dqdzu*We+(-We*Dqw-Wq)/Zi
3210    Dtedt=(Wte-Thet*Delr+We*Dte)/Zi+Dtemp
3215    Dqwdt=(Wq+We*Dqw)/Zi
3220    SUBEND   ! END OF 'M2' SUBPROGRAM


3225    DEF FNQvalue(SHORT Tx,R)     !FIGURE THE 'Q' VALUE
         GIVEN:
3230    Qvb=.053542*EXP(-5399.286*(1/(Tx+273.16)-3.5905E-3))*R
3235    RETURN Qvb !TAKE THE Q value BACK
3240    FNEND!


3245 Frame:SUB Frame(SHORT G(*),REAL Nrll,Tday$,Dqdzu,Dtdzu,
         Press,Frame_loc$,Frame_date$,Mhr)
3250    OPTION BASE 1
3255    DIM Zg(4)
3260     PLOTTER IS 13,"GRAPHICS"
3265     GRAPHICS
3270 SCALE Nrll-6,Nrll+60,-200,2400
3275 CLIP Nrll,Nrll+60,0,2400
3280 AXES 2,100,Nrll,0,6,2,3
3285 MOVE Nrll+26,-110
3290 LORG 5
3295 DEG
3300 LABEL USING "K";"Atmospheric Mixed Layer Movement 30
         Hours "&Tday$
```

```
3305  MOVE Nrll+26,-170
3310  LABEL USING "K";Frame_loc$&"     "&Frame_date$&"   LT D.
        BROWER  NPS"
3315 LDIR 90
3320    MOVE Nrll-4.5,600
3325    LABEL USING "K";"Mixed Layer(meters)"
3330    MOVE Nrll-4.5,1800
3335    LABEL USING "K";"DUCT HEIGHT (meters)"
3340 CSIZE 2.7,.6
3345 LDIR 0
3350  MOVE Nrll+30,1050
3355  LABEL USING "K";"Vertical Profile 'M-value' (every
        SIX nours)"
3360  FOR Cc=Nrll TO Nrll+Mhr STEP 12
3365    MOVE Cc,-30    !Print out time at bottom
3370    Bb=INT(Cc/2)
3375    Bob=FRACT(Cc/2)*60
3380    Bb=Bb MOD 24
3385    LABEL USING "ZZ,ZZ";Bb,Bob
3390    Bb=(Bb+3) MOD 24
3395    MOVE Cc+6,2370 ! PRINT OUT TIME AT TOP
3400    LABEL USING "ZZ,ZZ";Bb,Bbb
3405    NEXT Cc
3410    FOR Cv=1 TO 5  ! Label side
3415    MOVE Nrll-2,Cv*200
3420    LABEL USING "4D";Cv*200
3425    NEXT Cv
3430 MOVE Nrll,G(Nrll,1)
3435  GRAPHICS
3440  FOR V=Nrll+1 TO Nrll+Mnr! Draw out the max 'M' neight
        at the inversion
3445    DRAW V,G(V,1)
3450    NEXT V
3455    LINE TYPE 4
3460 MOVE Nrll,G(Nrll,1)*1.1
3465  FOR V=Nrll+1 TO Nrll+Mhr!Draw out the min 'M' neight
        above the inversion
3470    DRAW V,G(V,1)*1.1
3475    NEXT V
3480    LINE TYPE 2
3485    MOVE Nrll,G(Nrll,2)
3490    FOR V=Nrll+1 TO Nrll+Mhr! DRAW THE LIFTING
        CONDENSATION LEVEL
3495    DRAW V,G(V,2)
3500    NEXT V
3505    LINE TYPE 1!


3510 Profile:! COMPUTES AND PLOTS PREDICTED PROFILES
3515  SCALE -1.5,15,-1400,1200  ! Draw vertical lines in
        lower window
```

```
3520    LINE TYPE 3
3525     FOR D=1.5 TO 13.5 STEP 3
3530     MOVE D,-1200
3535     DRAW D,0
3540     NEXT D
3545     LINE TYPE 1      !Get set for upper window
3550    CLIP 0,15,-1200,1200
3555    AXES 1,100,15,0,3,2,7
3560    GRAPHICS
3565    Sbd=0  ! FLAG FOR SURFACE BASED DUCT WARNING TO PRINT
           OUT
3570    CSIZE 2.7,.6
3575     FOR Cv=1 TO 5    ! label left side
3580     MOVE -.5,Cv*200
3585     LABEL USING "4D";Cv*200
3590     NEXT Cv
3595     Zg(1)=0
3600     Zg(4)=1200   !


3605     FOR Pr=0 TO 4
3610     Pm=Pr*150
3615     Hrg=Nrl1+6+12*Pr          ! Pull out hours for profiles
3620     FOR I=1 TO 4        ! Determine multiples to use for
           altitude
3625     Zg(2)=G(Hrg,1)
3630     Zg(3)=G(Hrg,1)*1.1  ! TO SET INVERSION THICKNESS =.1*
           HEIGHT
3635     ! COMPUTES Q AND THETA
3640     Pp1=G(Hrg,4)+(I>=3)*G(Hrg,6)+(I=4)*Dqdzu*(1200-Zg(3))
3645     Pp2=G(Hrg,5)+(I>=3)*G(Hrg,7)+(I=4)*Dtdzu*(1200-Zg(3))
3650     ! COMPUTES PRESSURE ,VAPOR PRESSURE AND TEMP(K)
3655     P=Press-.120*Zg(I)
3660     E=P*Pp1/622
3665     T=Pp2-.0098*Zg(I)
3670     ! COMPUTES MODIFIED INDEX OF REFRACTION
3675     Pp(I)=77.6*P/T+373000*E/(T*T)+.157*Zg(I)
3680     NEXT I
3685     LORG 5 !Label bottom of 'M' profile
3690     SCALE 225,1050,-1400,1200
3695     MOVE Pm+375,-80
3700     LABEL USING "K";"350    400"
3705     MOVE Pp(1)+Pm,Zg(1)              ! Draw each profile
3710     FOR I=2 TO 4
3715     DRAW Pp(I)+Pm,Zg(I)
3720     NEXT I
3725     IF (Pp(3)<Pp(1)) OR (ABS(Pp(3)-Pp(1))<5) THEN GOSUB
           Sfc_duct
3730     LINE TYPE 3
3735     MOVE Pp(3)+Pm,Zg(3)
3740     DRAW Pp(3)+Pm,MAX(0,(Pp(3)-Pp(1))/(Pp(2)-Pp(1))*Zg(2)
```

```
        )
3745  LINE TYPE 1
3750  MOVE 375+Pm,-1150                        ! MOVE TO EACH SIX
        HOUR SPOT
3755  A=FNRelhum((G(Hrg,4)),(G(Hrg,5)))
3760  LABEL USING "3D.D";A
3765  NEXT Pr
3770  BEEP
3775  PAUSE
3780  EXIT GRAPHICS
3785  Hd$="N"
3790  INPUT "DO YOU WANT HARD COPY OUTPUT (N/Y)",Hd$
3795  IF Hd$[1,1]="N" THEN SUBEXIT
3800  PRINTER IS 0
3805  PRINT LIN(2)
3810  DUMP GRAPHICS
3815  IF NOT Sod THEN 3840
3820  PRINT LIN(2),"    The possibility of a surface
        based duct(SBD) is indicated and only"
3825  PRINT "due to the 'M' value greater at the surface
        than at the inversion"
3830  PRINT "height.  Variation in the vertical structure
        must be emphasized"
3835  PRINT "when briefing this forecast in that a SBD may
        not exist."
3840  PRINT LIN(1),"    This is a SIMPLIFICATION of the real
        structure."
3845  PRINT LIN(1),"    This display is divided into UPPER
        and LOWER windows:"
3850  PRINT "LOWER WINDOW displays the top and middle
        of the elevated layer and its"
3855  PRINT "    forecast continued movement for a thirty
        hour period after beginning."
3860  PRINT "    At the bottom is the Relative Humidity at
        each six hour period."
3865  PRINT "    The lightly dotted line is the lifting
        condensation level."
3870  PRINT "        [With enough moisture near the inversion,
        this can be used"
3875  PRINT "        as a flag for possible cloud formation,
        or for high mixed-"
3880  PRINT "        layer humidity, near the surface, to
        forecast fog.]"
3885  PRINT "UPPER WINDOW picks out M-value structure (
        using only 4 points)"
3890  PRINT "    at each six hour period and will indicate a
        surface based duct"
3895  PRINT "    only if the elevated M-value is less than
        or within 5 of"
3900  PRINT "    the surface M-value.  The sampled times are
        displayed at top."
```

```
3905    PRINT PAGE
3910    SUBEXIT
3915 Sfc_duct:  LORG 1
3920    BEEP
3925    LDIR 90
3930    MOVE Pp(3)+Pm-5,Zg(3)+20
3935    LABEL USING "K";"Surface Duct"
3940    Sbd=1
3945    LDIR 0
3950    LORG 5
3955    RETURN
3960 SUBEND!


3965    DEF FNRelhum(Q,T)
3970    Tl=T-.0098*10
3975    C=23.84-2948/Tl-5.03*LGT(Tl)
3980    P=1012-.120*10
3985    Relhum=MIN(100,Q*100/(625*10^C/P))
3990    RETURN Relhum
3995    SUBEND!


4000    SUB We2(Zi,Zlcl,Dte,Dqw,Qs,Thrl,Qliq,Thl,Tsfc,Ust,Tst,
        Qst,Tstv,We2,Delr2,Tsky) ! NEED TO CALL PARCEL
        FIRST
4005    Dth=Dte-2500*Dqw
4010    Thr=Thrl+273.16
4015    Th=Thl+273.16
4020    Epsilon=.622 !RATIO OF WATER AND AIR
4025    Sigma=4.61E-11 ! STEFANS CONSTANT RELATING TEMP TO
        BLACK BODY RADIATION
4030    Wl=Qliq*1250
4035    Emiss=MAX(0,1-EXP(-(Zi-Zlcl)*.138*Wl/2))! EMISSIVITY
4040    Tc=Th-.0098*Zlcl   ! TEMP AT BOTTOM OF CLOUD
4045    Tb=Thr-.0098*Zi    ! TEMP AT TOP OF CLOUD
4050    Tbar=(Tb+Th)/2
4055    Dqsdt=.622*Qs*(2500/(.287*Tbar*Tbar))! Thr IS THETA
        AT THE CLOUD TOP
4060    Beta=(1+Th*(1+Epsilon)*Dqsdt)/(1+2500*Dqsdt)! L&L/Cp<-
        --2500      Cp=1
4065    D2=Beta*Dte-Tbar*Dqw          ! IF NEGATIVE, THEN CLOUD
        TOP INSTABILITY
4070    Dthl=Dth-(Thr-Th)
4075    Dl=Dthl*(1+Epsilon*Qs)+Epsilon*Tbar*Dqw ! QV=QS IN A
        CLOUD
4080    See=MIN(1,MAX(0,Zlcl/Zi))     ! TRAP SEE BETWEEN 0 AND 1
4085    DEF FNHvi(A)=MAX(0,A)         ! HEAVISIDE FUNCTION
4090    Rb=Emiss*Sigma*(Tb^4-Tsky^4)! SHOULD BE POSITIVE
        UNDER MOST
4095    Rc=Emiss*Sigma*(Tsfc^4-Tc^4)! NORMAL CONDITIONS
```

```
4100   IF See=1 THEN Rb=Rc=0
4105   Wth=-Ust*Tst
4110   Wq=-Ust*Qst/1000  ! USING GRAMS PER GRAM
4115   Wthv=-Ust*Tstv
4120   Wthe=Wth+2500*Wq
4125   M1=(2-See)*See*FNHvi(Wthv)+(1-See)*(1-See)*FNHvi(Beta*
          Wthe-Th*Wq)
4130   N1=(2-See)*See*FNHvi(-Wthv)+(1-See)*(1-See)*FNHvi(-
          Beta*Wthe+Th*Wq)
4135  M2=See*See*(FNHvi(Rb)-Rc)+(1-See)*(1-See)*Beta*Rc+(1-
          See*See)*Beta*FNHvi(Rb)
4140   N2=See*See*FNHvi(-Rb)+(1-See*See)*Beta*FNHvi(-Rb)
4145   M3=(1-See*See)*FNHvi(-D2)
4150   N3=See*See*D1+(1-See*See)*FNHvi(D2)
4155   We2=(.2*(M1+M2)-(N1+N2))/(N3-.2*M3)   !A=.2    RATIO OF
          ENTRAINMENT ENERGY
4160   IF We2>0 THEN GOTO 4135                      ! TO TOTAL TKE
4165   IF (D2<0) AND (See<1) THEN We2=.005*(1-See*See)!CLOUD
          TOP INSTABILITY
4170   IF (D2<0) AND (See=1) AND (Wtnv>0) THEN We2=
          .001!ENCROACHMENT
4175   IF (D2<0) AND (See=1) AND (Wtnv<0) THEN We2=.0005
          !STABLE ENCROACHMENT
4180   IF We2<0 THEN We2=.0001
4185   Delr2=Rb-Rc    ! DONE HERE CALCULATED FROM THE WATER
          CONTENT, TEMP OF SKY, CLOUD EMISSIVITY (THICKNESS
          OF CLOUD)             TOP MINUS BOTTOM
4190   SUBEND!


4195 SUB Parcel0(The,Ql0,Z,Rh,Tn,Qv,Ql,Zs)
4200 Gam=.0098
4205 Gamdew=.00804
4210 Lcp=2.430
4215 Qq=Qt=Ql0
4220 Zz=0
4225 GOSUB Td_find
4230 Tdl0=Td
4235 Zz=Z
4240 Thr=The-Lcp*Qt
4245 GOTO 4345
4250 Thetn:Th=Thez-Lcp*10
4255 Cycle:Tdo=Th-Gam*Z
4260 T=Tx=Tdo
4265 Zz=0
4270 GOSUB Qvcal
4275 Qv=Qvo
4280 GOSUB Dqdtcal
4285 Dthe=(Thez-(Th+273.16)*(1+Lcp*Qv/(T+273.16))+273.16)/(
       1+Lcp*Qv/(T+273.16)+(Th+273.16)/(T+273.16)*Lcp*Dqdt)
4290 IF ABS(Dthe)<.0001 THEN RETURN
```

```
4295 Th=Th+Dtne
4300 GOTO Cycle
4305 Dqdtcal:Tx=Tdo+.001
4310    GOSUB Qvcal
4315    Dqdt=(Qvb-Qv)/.001
4320    RETURN
4325 Qvcal: Qvb=5.3542*EXP(-5399.286*(1/(Tx+273.16)-3.5905E-
          3))
4330      Sig=EXP(-1.1384E-4*Zz)
4335    Qvb=Qvb/Sig
4340      RETURN
4345    Zs=(Thr-Td10)/Gamdew
4350    IF Zs<0 THEN Zs=0
4355    IF Z>=Zs THEN GOTO 4400
4360    Th=Thr
4365    Tx=Th-Gam*Z
4370    Zz=Z
4375    GOSUB Qvcal
4380    Rn=Qt/Qvb*100
4385    Qq=Qv=Qt
4390    GOSUB Td_find
4395    GOTO 4420
4400    Thez=The
4405    GOSUB Theth
4410    Rh=100
4415    Td=Th-Gam*Z
4420    Ql=Qt-Qv
4425      SUBEXIT
4430 Td_find:    Sig=EXP(-1.1384E-4*Zz)
4435    Qx=Qq*Sig
4440      Td=5399.286/(21.064-LOG(Qx))-273.16
4445     RETURN
4450     SUBEND!


4455     SUB Shrtwv(Theta,Qlbm,Zc,Zb,Qt,Dtemp)! ADDED BY
             CHRIS FAIRALL  9FEB81
4460    IF (Zc>Zb) OR (Theta=PI/2) THEN Dtemp=0
4465    IF (Zc>=Zb) OR (Theta=PI/2) THEN SUBEXIT
4470    Qlbm=MAX(.00005,Qlbm)
4475    Qq=Qlbm/2
4480    DIM Xnd(4),Dr(4)
4485    Cldthk=Zb-Zc
4490    Delz=Cldthk
4495    Dr(1.0)=2.5
4500    Dr(2)=5
4505    Dr(3)=10
4510    Dr(4)=20
4515    Sh=(Qt-Qq/Cldthk*Delz/2)*1.19   !WATER VAPOR
4520    Qq=Qq*1.19   !LIQUID WATER
4525    Rm=(4774.648*Qq)^.333
```

```
4530    FOR I=1.0 TO 4   ! XND IS THE XLOUD DROPLET SPECT
4535      Xnd(I)=.829963*EXP(-LOG(Dr(I)/Rm)*LOG(Dr(I)/Rm)*
             4.4164)*1E8
4540    NEXT I
4545    CALL Kannrad(Cldthk,Sh,Xnd(*),Theta,0,Fheat,Ftop,
           Fbotdir,Fbotdif)
4550    ! Fbotdir  DOWNWARD DIRECT RAD AT CLOUD BOTTOM
4555    ! Fbotdif  DOWNWARD DIFFUSE RAD AT CLOUD BOTTOM
4560    ! Ftop     DOWNWARD DIRECT RAD AT CLOUDTOP
4565    ! Theta    ZENITH ANGLE
4570    Dtemp=Delz*Fheat/Zb/60
4575    SUBEND
4580    SUB Int779(Nxy,X,Xarray(*),Yarray(*),Y,Slope,Ix)
4585    OPTION BASE 1
4590    Ix=MIN(MAX(1,Ix),Nxy-1)
4595    IF Xarray(Ix)<X THEN 4615
4600    IF Ix<=1 THEN 5020
4605    Ix=Ix-1
4610    GOTO 4595
4615    IF X<=Xarray(Ix+1) THEN 4635
4620    IF Ix+1>=Nxy THEN 5020
4625    Ix=Ix+1
4630    GOTO 4595
4635    Slope=(Yarray(Ix+1)-Yarray(Ix))/(Xarray(Ix+1)-Xarray(
           Ix))
4640    Y=Slope*(X-Xarray(Ix))+Yarray(Ix)
4645    GOTO 4655
4650    Ix=-999
4655    SUBEND
4660    ! SUB A52 - INITIALIZE XKV ARRAY
4665    SUB A52(Xkv(*),U)
4670    ! DISP "A52"
4675    ! U IS PATH IN G/CM^2
4680    OPTION BASE 1
4685    MAT Xkv=ZER
4690    Xkv(6)=.05/U^.39!.022
4695    Xkv(7)=.09/U^.39!.094
4700    Xkv(8)=.26/U^.39!.169
4705    Xkv(9)=.28/U^.26!.145
4710    Xkv(10)=.36/U^.26!.211
4715    Xkv(11)=.66/U^.53!.591
4720    Xkv(12)=.97/U^.53!.943
4725    Xkv(13)=1.06/U^.53!.943
4730    Xkv(14)=.39/U^.68!.76
4735    Xkv(15)=.31/U^.68!.685
4740    SUBEND
4745    ! SUB A20 - COMPUTE NEEDED ELEMENTS FOR AUGMENTE
           MATRIX A
4750    SUB A20(A(*),T,Al,Be,P,Xk,Fi(*),Qext(*),Dr(*),D,Sa(*),
           Af(*),Sh,Xkv(*),Xnd(*),Ag,Iw,Xmu,Tau(*))
4755    OPTION BASE 1
```

```
4760  ! DISP "A20"
4765  CALL A28(G,T,Om,Dr(*),Xnd(*),Qext(*),D,Sa(*),Af(*),Sh,
        Xkv(*),Iw,Tau(*))
4770  Fo=Fi(Iw)
4775  Fq=G*G
4780  G=G/(1+G)
4785  T=(1-Om*Fq)*T
4790  Om=(1-Fq)*Om/(1-Om*Fq)
4795  D1=1-Om
4800  D2=1-Om*G
4805  Xk=(3*D1*D2)^.5
4810  P=(3*D1/D2)^.5
4815  D3=1-Xk*Xk*Xmu*Xmu
4820  Al=3*Om*(Fo/PI)*Xmu*Xmu*(1+G*D1)/(4*D3)
4825  Be=3*Om*(Fo/PI)*Xmu*(1+3*G*D1*Xmu*Xmu)/(4*D3)
4830  A(1,1)=1+2*P/3
4835  A(1,2)=1-2*P/3
4840  A(1,3)=Al+2*Be/3
4845  A(2,1)=(1-Ag-2*(1+Ag)*P/3)*EXP(-Xk*T)
4850  A(2,2)=(1-Ag+2*(1+Ag)*P/3)*EXP(Xk*T)
4855  A(2,3)=((1-Ag)*Al-2*(1+Ag)*Be/3+Ag*Xmu*(Fo/PI))*EXP(-
        T/Xmu)
4860  .SUBEND
4865  ! SUB A30 - COMPUTE NET FLUXES - FTOP AND ARRAY FL
4870  SUB A30(Fl,Fbotdir,Fbotdif,Ftop,Ftopd,X(*),Xk,Fi(*),T,
        Al,Be,P,Iw,Xmu)
4875  OPTION BASE 1
4880  ! DISP "A30"
4885  T0=0
4890  I0=X(1)*EXP(-Xk*T0)+X(2)*EXP(Xk*T0)-Al*EXP(-T0/Xmu)
4895  I1=P*(X(1)*EXP(-Xk*T0)-X(2)*EXP(Xk*T0))-Be*EXP(-T0/
        Xmu)
4900  Fd=Fi(Iw)*Xmu     !DOWNWARD COMP AT CLOUD TOP IW BAND,
        PERPIND TO HORIZONTAL
4905  Ftop=Ftop-PI*(I0-2/3*I1)+Fd   !NET (D-U) AT CLOUD TOP,
        TOTAL
4910  Ftopd=Ftopd+Fd   !TOTAL DOWNWARD COMP
4915  I0=X(1)*EXP(-Xk*T)+X(2)*EXP(Xk*T)-Al*EXP(-T/Xmu)
4920  I1=P*(X(1)*EXP(-Xk*T)-X(2)*EXP(Xk*T))-Be*EXP(-T/Xmu)
4925  Fl=Fl+4/3*PI*I1   !NET AT LEVEL
4930  Fl=Fl+Fd*EXP(-T/Xmu)   !TOTAL NET (DIF+DIRECT) LEVEL I
4935  Fbotdif=Fbotdif+PI*(I0+2/3*I1)
4940  Fbotdir=Fbotdir+Fd*EXP(-T/Xmu)
4945  SUBEND
4950  ! SUB A28 - AVERAGE SA,AF ARRAYS AND STORE IN OM,G;
        COMPUTE T
4955  SUB A28(G,T,Om,Dr(*),Xnd(*),Qext(*),D,Sa(*),Af(*),Sh,
        Xkv(*),Iw,Tau(*))
4960  ! DISP "A28"
4965  OPTION BASE 1
4970  Om=G=Ts=0
```

```
4975    FOR J=1 TO 4
4980    Tau(J)=Qext(Iw,J)*PI*(Dr(J)*1E-6)^2*Xnd(J)*D
4985    Ts=Ts+Tau(J)
4990    NEXT J
4995    T=Ts
5000    FOR J=1 TO 4
5005    Om=Om+Sa(Iw,J)*(Tau(J)/Ts)
5010    G=G+Af(Iw,J)*Tau(J)/Ts
5015    NEXT J
5020    Vp=Sh*D*1E-4
5025    Om=Om/(1+Xkv(Iw)*Vp/T)
5030    SUBEND
5035    ! SUB A100 - COMPUTE QEXT,SA,AF ARRAYS - ROUTINE FROM
           A. GOROCH
5040    SUB A100(Qext(*),Sa(*),Af(*),Dr(*))
5045    ! DISP "A100"
5050    OPTION BASE 1
5055    DIM X19(15),Xn9(15),Xk9(15)
5060    DATA 0.25,0.35,0.45,0.55,0.65,0.75,0.85,0.95,1.05,1.15
5065    DATA 1.25,1.35,1.45,1.55,1.65
5070    DATA 1.362,1.345,1.335,1.333,1.332,1.3,1.329,1.327,
           1.326,1.325
5075    DATA 1.323,1.321,1.320,1.318,1.316
5080    DATA 2.5,5,10,20
5085    RESTORE 5060
5090    MAT READ X19,Xn9,Dr
5095    MAT Xk9=ZER
5100    REM EVALUATE EXTINCTION USING DEIRMENDJIAN
           APPROXIMATION
5105    FOR Ix9=6 TO 15
5110    X10=X19(Ix9)
5115    Xn0=Xn9(Ix9)
5120    FOR I=1 TO 4
5125    R2=Dr(I)
5130    R0=4*PI*R2/X10*(Xn0-1)
5135    Qsca=Qext(Ix9,I)=2
5140    Sa(Ix9,I)=Qsca/Qext(Ix9,I)
5145    IF Sa(Ix9,I)=1 THEN Sa(Ix9,I)=.9999999999
5150    Af(Ix9,I)=1.8*(.5+EXP(-4*R0)/R0+(EXP(-4*R0)-1)/(4*R0)^
           2)
5155    NEXT I
5160    NEXT Ix9
5165    ! DISP ""
5170    SUBEND
5175    SUB Kannrad(Cldthk,Sh,Xnd(*),Theta,Itest,Fheat,Iinc0,
           Fbotdir,Fbotdif)
5180    ! DISP "KAHNRAD"
5185    OPTION BASE 1
5190    DIM A(2,3),R(3),X(2)
5195    DIM Qext(15,4),Sa(15,4),Af(15,4)
5200    DIM Dr(4),Tau(4),Alam(15)
```

```
5205    DIM Fi(15),Xkv(15)
5210    ! I. INITIALIZATION
5215    DATA .0165,.1580,.2839,.2765,.2318,.1822,.1435,.1149,
           .0948,.0792
5220    DATA .0643,.0518,.0424,.0348,.0238
5225    DATA .2,.5355,.803,.909,.953,.960,.960,.920,.933,.940,
           .850,.780,.770,.830,.910
5230    RESTORE 5215
5235    MAT READ Fi,Alam
5240    U=MAX(.05,Sh*Cldthk*1E-4)
5245    Fbotdir=Fbotdif=Ftop=Ftopd=Ftopdir=0
5250    IF Itest=1 THEN Theta=PI/4
5255    Xmu=COS(Theta)
5260    IF Xmu=0 THEN 5285
5265    Secmu=1/Xmu
5270    FOR I=1 TO 15
5275    Fi(I)=Fi(I)*Alam(I)^Secmu
5280    NEXT I
5285    Ag=.1    ! SURFACE ALBEDO
5290    IF Xmu>.7 THEN Ag=.05
5295    Delz=Cldthk
5300    Fl=0
5305    D=Delz
5310    CALL A100(Qext(*),Sa(*),Af(*),Dr(*))
5315    CALL A52(Xkv(*),U)
5320    ! II. SOLUTION OF EQUATIONS
5325    FOR Iw=6 TO 15
5330    CALL A20(A(*),T,Al,Be,P,Xk,Fi(*),Qext(*),Dr(*),D,Sa(*)
           ,Af(*),Sh,Xkv(*),Xnd(*),Ag,Iw,Xmu,Tau(*))
5335    ! PERFORM GAUSS ELIMINATION ON MATRIX A
5340    FOR L=1 TO 2
5345    Il=L
5350    Dd=A(L,L)
5355    IF ABS(Dd)>.000001 THEN 5405
5360    Il=Il+1
5365    IF Il>2 THEN 5545
5370    FOR Iwi=1 TO 3
5375    R(Iwi)=A(L,Iwi)
5380    A(L,Iwi)=A(Il,Iwi)
5385    A(Il,Iwi)=R(Iwi)
5390    NEXT Iwi
5395    Dd=A(L,L)
5400    GOTO 5355
5405    FOR Ibi=1 TO 3
5410    A(L,Ibi)=A(L,Ibi)/Dd
5415    NEXT Ibi
5420    FOR J=L+1 TO 2
5425    Dd=A(J,L)
5430    FOR K=1 TO 3
5435    A(J,K)=A(J,K)-Dd*A(L,K)
5440    NEXT K
```

```
5445     NEXT J
5450     NEXT L
5455     FOR K=2 TO 2 STEP -1
5460     FOR J=K-1 TO 1 STEP -1
5465     A(J,3)=A(J,3)-A(J,K)*A(K,3)
5470     A(J,K)=0
5475     NEXT J
5480     NEXT K
5485     FOR I=1 TO 2
5490     X(I)=A(I,3)
5495     NEXT I
5500     CALL A30(Fl,Fbotdir,Fbotdif,Ftop,Ftopd,X(*),Xk,Fi(*),
            T,Al,Be,P,Iw,Xmu)
5505     NEXT Iw
5510     ! III.  OUTPUT MODULE
5515     Fheat=(Ftop-Fl)/D*35.014
5520     Iinc0=Ftopd
5525     Ftop=Iinc0=Iinc0/1.7136
5530     Fbotdir=Fbotdir/1.7136
5535     Fbotdif=Fbotdif/1.7136
5540     SUBEND
5545     PRINT "INDETERMINATE"
5550     SUBEND
5555     SUB Sky2(Zi,Nsnd,Pot_temp(*),Zsnd(*),Spec_num(*),Tsky,
            Ftop)
5560     DATA 0,.00001,.0000215,.0000464,.0001,.000215,.000464,
            .001,.00215,.00464,.01,.0215,.0464,.1,.215,.464,1,
            2.15,4.64,10,21.5,46.4,-999
5565     DATA 0,1.86,2.58,4.11,5.72,7.81,11.4,14.6,18.3,23.6,
            27.7,31.9,37.4,41.7,46.2,52.9,59,66.6,78.8,88.1,
            95.1,98.8,-999
5570     DATA .0098,1.225,10094,4.61E-11,0,1,0
5575     OPTION BASE 1
5580      DIM Tu(23),Temis(23),Emit(2),Thrsnd(30),Qtsnd(30)
5585      RESTORE 5560
5590      MAT Qtsnd=Spec_num
5595      MAT Thrsnd=Pot_temp
5600      MAT READ Tu,Temis
5605      READ Gad,Rno0,Zscale,Sig,U,Ii,S
5610      Nemis=22
5615     ! THRSND() IS TH RADIOSND
5620     ! ZSND() IS ALTI IN M,RADSN
5625     ! NEMIS IS # OF EMISSIVITY POINTS IN TEMISS
5630     ! TU(23),U DATA
5635     ! TEMIS(23),EMISSIVITY DATA
5640     ! ITOP IS INDEX FOR ZSND=ZI, IE WHAT LEVEL IN RADSND
            IS AT INVERSION
5645     ! NSND IS NUMBER IS POINTS IN RADIOSOND
5650     ! ICLOUD IS INDEX OF UPPER LEVEL CLOUDS
5655     Icloud=Nsnd   !ASSUME NO UPPER LEVEL CLOUDS
5660      Nsnd=Nsnd-1
```

```
5665     IF Nsnd<=0 THEN SUBEXIT
5670    FOR Itop=1 TO Nsnd
5675      IF Zsnd(Itop)>Zi THEN GOTO 5685
5680     NEXT Itop
5685     Itop=Itop-1
5690    DISP "SKY2"
5695    Tts=Thrsnd(Itop)-Gad*Zsnd(Itop)
5700    Emit(Ii)=0
5705    FOR I=Itop+1 TO Nsnd-1
5710    Ii=3-Ii
5715    IF I>Icloud THEN GOTO 5785
5720    U=U+Qtsnd(I)*(.00005*(Zsnd(I+1)-Zsnd(I-1))*Rho0*EXP(-
         Zsnd(I)/Zscale))
5725    CALL Int779(Nemis,U,Tu(*),Temis(*),Emit(Ii),Es,Ie)
5730    Tt=Thrsnd(I)-Gad*Zsnd(I)
5735    S=S-Emit(Ii)*Sig*((Tt+273.16)^4-(Tts+273.16)^4)/100
5740    Tts=Tt
5745    NEXT I
5750    Tt=Thrsnd(Nsnd)-Gad*Zsnd(Nsnd)
5755    U=U+Qtsnd(Nsnd)*.0001*(Zsnd(Nsnd)-Zsnd(Nsnd-1))*Rho0*
         EXP(-Zsnd(Nsnd)/Zscale)
5760    CALL Int779(Nemis,U,Tu(*),Temis(*),Emit(Ii),Es,Ie)
5765    S=S+Sig*(Tt+273.16)^4*Emit(Ii)/100
5770    Icloud=Nsnd
5775    Ftop=0
5780    GOTO 5795
5785    Tt=Thrsnd(Icloud)-Gad*Zsnd(Icloud)
5790    Ftop=Sig*(Tt+273.16)^4
5795    Tsky=((Ftop*(1-Emit(Ii))+S)/Sig)^.25
5800    DISP ""
5805    SUBEND
5810    SUB Zenith(Time,Julday,Lat,Theta)
5815    RAD
5820      Hr=Time/3600 MOD 24-12
5825      Latr=Lat*.017453
5830      H=Julday*.017214
5835    Decl=.006913-.399912*COS(H)+.070257*SIN(H)-.006758*
           COS(2*H)+.000907*SIN(2*H)-.002697*COS(3*H)+
           .000143*SIN(3*H)
5840      Theta=ACS(SIN(Latr)*SIN(Decl)+COS(Latr)*COS(Decl)*
           COS(Hr*PI/12))
5845     IF Theta>PI/2 THEN Theta=PI/2
5850      SUBEND
```

MAJOR PROGRAM VARIABLES IN PREDICTION CODE:

Alpha_t ... ratio of heat transfer to momentum transfer
    exchange coefficient for neutral conditions (Psi=0)

Aws ... subsidence rate value at initial inversion
    height[m/s]

Cdn ... neutral drag coefficient

Ctn_sqrt ... square root of the temperature structure
    function parameter

Ddqwdt ... rate of change of specific humidity within the
    layer [g/kg-s]

Ddtedt ... rate of change of equivalent potential
    temperature within the layer [K/s]

Delr ... radiation flux divergence at cloud top [km/s]

Deltim ... prediction time step [1800 sec]

Dhdt ... rate of change of the mixed layer height and is
    the sum of entrainment and subsidence effects [m/s]

Dqdzu ... lapse rate of specific humidity above the
    layer [g/kg-km]

Dqw ... jump in specific humidity at the inversion [g/kg]

Dqwdt ... rate of change of specific humidity jump [g/kg-s]

Dtdzu ... lapse rate of potential temperature above the
    layer [K/km]

Dte ... jump in equivalent potential temperature at the
    layer [K]

Dtedt ... rate of change of equivalent potential temperature

Dtedzu ... lapse rate of equivalent potential temperature
    above the layer [k/km]

Dth ... jump in potential temperature at the layer [k]

Kkk ... Von Karman constant (.35)

Lcp ... liquid water content

Mixq ... initial value of mixed layer specific humidity

Mixtemp ... initial value of mixed layer potential
    temperature

Nrll ... beginning in half hour period [e.g. 1200=24]

Nrad ... 100 times the ratio of buoyancy in clouds

Press ... surface pressure, default to 1012 mb unless
    entered from IREPS [mb]

Psil ... stability correction to logarithmic surface layer
    wind profile. Determined from surface stability.
    (Businger et al, 1971)

Psi2 ... stability correction to logarithmic surface layer
    temperature and humidity profiles. determined from
    surface stability. (Businger et al, 1971)

Q10 ... Qp ... computed well-mixed specific humidity which
    is assigned to the 10 meter level [g/kg]

Qst ... surface layer specific humidity scaling parameter,
    -Wq/Ust,[g/kg]

Qw ... total (liquid + vapor) specific humidity [g/kg]

S ...surface layer stability (S=Z/L, L=Monin-Obunkov length)

T10 ... well-mixed potential temperature which is assigned

to the 10 meter level [K]

Te ... equivalent potential temperature

Th ... well-mixed potential temperature in degrees Kelvin

Tsfc ... surface temperature [K]

Tst ... surface layer temperature scaling parameter [K]

Tstv ... surface layer virtual potential temperature scaling
parameter [K]

U10 ... well-mixed wind speed which is assigned to the 10
meter level [m/s]

Ust ... surface layer momentum scaling parameter [m/s]

Vdte ... advection above tne layer

We ... entrainment rate [m/s]

Ws ... subsidence rate [m/s]

Wq ... surface flux of specific humidity [g/g]

Wst ... mixed layer convective scaling velocity [m/s]

Wto ... surface flux of temperature [K-m/s]

Wtv ... surface flux of vertical potential temperature
(buoyancy flux) [K-m/s]

Zi ... height of tne layer [m]

Zlcl ... lifting condensation level [m]

Zo ... surface roughness parameter for momentum [m]

Zot ... surface rougnness parameter for temperature and
humidity [m]

Zws ... initial height used for subsidence rate reference [m]

MAIN PROGRAM

COMMON VARIABLES:

Air	115	1070	1850			
Change	115	1070				
Coml(*)	120					
Delta	115	1070	1850			
Envnam$(*)	125	945	1005	1055		
Envsq(*)	120	930	965	995	1055	1060
Evap$	95	1060				
Height$	95					
Height(*)	110	1065	1080	1090	1095	1455	1465
		1480	1620	1630	1865	
Htzero	115	1070				
Loc$	95	440	490	530	1060	1335	1845
		1940	2630	2900		
Losnam$(*)	125					
Lossq(*)	120	930				
Munits(*)	110	1065	1865			
Name$	95	1060				
Nmax	115	1070	1075	1080	1090	1095	1455
		1460	1465	1480	1620	1625	1630
		1865	1955			
Nunits(*)	110	1065				
Presur(*)	105	1065	1080	1865		
Przero	115	1070	1110	1850		
Recenv	115					
Relhm	115	1070	1850			
Relhum(*)	105	1065	1085	1865		
Sea	115	445	840	845	850	1070	1850
		2370				
Sysnam$(*)	125					
Syssq(*)	120	930				
Temper(*)	105	1065	1085	1090	1865	
Time$	95	440	490	530	1060	1335	1845
		1945	2630	2900		
Type$	95	1060				
Wind	115	575	580	1070	1350	
Wmo$(*)	100	1060				
Wmoht$	100	1060				

VARIABLES:

Aa	265	285	290	295	300
Alpha_t	190	2330	2430	2470	2490
Aws	2130	2280	2285		
Cc	3000	3005	3010	3015	
Cdn	2350	2355	2375	2385	2430	2470

Ctn_sqrt	2380	2385	2430	2470		
D	1780	1785	1790			
Date$	220					
Ddqwdt	2235	2265				
Ddtedt	2235	2275				
Delr	2235					
Deltim	190	2245	2250	2260	2265	2275	2285
Dhdt	2235	2245				
Digit_top	1100	1460	1625	1860		
Dqdzu	1920	2115	2205	2220	2565	
Dqp	1915	2110	2120	2270		
Dqw	2120	2235	2265	2270	2310	
Dqwdt	2235	2250				
Dtdzu	1930	2115	2205	2565		
Dte	2110	2235	2275	2310		
Dtedt	2235	2260				
Dtedzu	2115	2205	2235			
Dth	1925	2110	2310			
Dummy	1035	1040	1045	1050		
Flag_data	360	1130	2525			
Flag_rev	310	365	1125			
Frame_date$	155	1945	2565			
Frame_loc$	155	1940	2565			
Ftop	1955					
G(*)	180	550	630	675	745	770	780
	1120	2025	2050	2060	2070	2215
	2240	2245	2255	2270	2305	2310
	2345	2565	2655	2660	2665	2670
	2805	2825	2855	2870	2940	2950
G1	2645	2650	2655	2660	2665	2670	2675
G2	2650	2670				
G3	2655	2670				
G4	2660	2670				
G5	2665	2670				
Hd$	430	470	1835	2585	2590	2595	2600
	2625	2690	2895	2905	3020	3030
	3040					
Hight$	1060					
I	940	945	950	960	990	995	1005
	1010	1015	1020	1075	1080	1085
	1090	1095	1100	1105	1860	1865
	1870	2040	2045	2050	2055	2060
	2080	2085	2810	2825	2855	2875
	2945	2950	2955			
Idayl	755	765	775			
Ier	910	915	920	925		
Inll$	535	540	545	550	565	595	610
	625					
Inl2$	645	650	655	660	665	670	675
J	160	960	965	970	2020	2065	2070
	2075	2175	2185	2210	2215	2225

		2240	2245	2255	2270	2305	2310
		2325	2345	2850	2855	2365	
Julday	170	445	490	495	2230		
K	2795	2805	2825	2830	2845	2855	2870
		2885					
Kkk	190	2375	2380	2385	2430	2470	2490
		2495					
L	1235	1240	1250	1255	1270	1275	1280
		1285	1295	1300	1305	1310	1430
		1435	1440	1445	1460	1465	1470
		1625	1630	1635	2825	2830	2835
		2840					
L$	165	2630	2635				
Lat	175	445	500	505	2230		
Lcp	2095	2105	2110	2115	2205	2300	2305
		2310					
Ll	1265	1275	1280	1290			
Mass$	75	910	920				
Mhr	1960	1980	2175	2565	2645		
Mixq	1650	1660	1665	1685	1725	1730	1910
		1915					
Mixtemp	1490	1515	1525	1540	1575	1580	1900
		1925					
Mmm	1530	1650	1675	1780			
Mult	2490	2500	2505				
Nd	2055	2060	2065				
Nrl	2035	2040	2055	2060	2070	2080	
Nrll	565	620	630	675	745	755	770
		780	1980	1990	2020	2025	2035
		2145	2150	2155	2175	2210	2215
		2565	2645	2735	2740	2745	2755
		2765	2775	2785	2805	2825	2830
		2850	2870	2915	2925	2935	2940
		2945	2965	2980	2990	3000	
Nrec	1020	1030	1045				
Numhr	1980	2085					
O2	2220	2235					
P	2815	2855	2860				
Pot_temp(*)	165	1090	1455	1465	1480	1865	1955
Press	1110	1115	2565				
Psil	2405	2420	2430	2465	2470	2495	
Psi2	2410	2425	2430	2460	2470	2490	
Q$	570	585	590	635	680	695	720
		725	730	735			
Q10	2195	2235	2255				
Qdelta	2370	2385	2505				
Qp	1910	2105	2125	2195	2255	2370	
Qstar	2235	2505	2510				
Qw	2125	2250	2255	2305			
Rc$	355	390	400	405	410	415	
Rec	995	1000	1005	1050	1055	1060	

Run$	2170	2210	2215				
S	2385	2400	2420	2425	2430	2435	2440
	2450	2455	2470	2475	2480		
S1	2385	2435	2440	2475	2480		
So	2385	2390	2395	2430	2470		
Spec_hum(*)	165	1085	1620	1630	1645	1865	1955
Stick$(*)	155	190	1440				
T	2090	2095	2100	2295	2300		
T10	1900	2015	2190	2235			
Tday$	220	225	235	240	445	1335	1975
	2565	2630					
Tdelta	2365	2385	2500				
Te	2105	2260	2305				
Th	2015	2090	2105	2110	2115	2190	2205
	2305	2310	2365	2385	2510		
Theta	2230	2235					
Timesec	2225	2230					
Top_inv_q	1675	1685	1690	1710	1735	1915	1920
Top_inv_temp	1530	1540	1545	1565	1585	1925	1930
Top_q	1700	1710	1740	1920			
Top_q_alt	1700	1710	1740	1920			
Top_temp	1555	1565	1590	1930			
Top_temp_alt	1555	1565	1590	1930			
Tsfc	850	2235	2365				
Tsky	1955	2235					
Tstar	2235	2500	2510				
Tstv	2235	2510					
Tt	2100	2105	2110	2115	2205	2290	2295
	2305	2310					
U10	2345	2350	2355	2385	2495		
Ustar	2235	2495					
Vdt	1995	2005					
Vdte	2005	2275					
Vss	2555	2565	2570				
Win	455	460	465	640	665	670	675
		685	690	705	710	715	760
		765	770	775	780	785	795
		800					
Win1	750	765	770				
Wind_begin1	575	600	605	610	625	630	
WindIn(*)	155	460	520	565	630	670	675
		710	745	765	770	775	780
		1250					
Wn	455	560	685	705	760	800	1235
Ws	205	1935	2130	2235	2280		
Ws1	205	445	825	830	1415	1935	
Wtv	2235						
X1	2450	2465					
X2	2455	2460					
X5	2060	2070					
Z	190	2375	2380	2385	2490	2495	

```
Zi                      1475    1490    1505    1525    1565    1580    1585
                                1645    1665    1710    1715    1730    1735
                                1905    1920    1930    1955    1990    2025
                                2090    2100    2130    2135    2180    2185
                                2235    2245    2280    2290    2295
Zil                     2180    2290
Zi3                     1475    1715    1905
Zlcl                    2235    2240
Zo                      2375    2495
Zot                      190    2380    2490
Zsnd(*)                  165    1095    1955
Zws                     2135    2285

USER DEFINED FUNCTIONS:
 FNQvalue               1085    2370
 FNRelhum               2665    2940    2950

SUB PROGRAMS:
 Frame                  2565
 M2                     2235
 Sky2                   1955
 Zenith                 2230

JUMP TARGETS:
 155                      80
 190                     185
 220    Start:          875
 255    Option:
 260    Menu:           290     295     300     305     360     410     415    1030
                                1040    2335    2525    2570
 310    Start_out:      300
 315    Start_out_ag    405
 350    Revchange:      300     400     420
 425    List_curr:      415
 490    Jullat:         320     415
 515    Enter_winds:    325     415
 530                    525     540
 610                    590
 645    One_wind:       655     660     805
 695    Print_wind:     650     740     810
 745                    730
 795    Fixwind:        735     800
 815    Subsidence:     330     415
 840    Sea_temp:       335     415
 860    Assig_error:    905
 880    No_data:        860     915     925
 900    Ireps_data:     245
 960    All_out:        935
 975    All_full:       955
 980    Disp_data:      315     415    1045
1020    Pick_data:     1000
```

```
1110                     1080
1140 Plt_struct:          340    415   1790
1770                     1785
1885                     1835
1900 Run:                 310    345
2045                     2050   2085
2175 Looper:
2340 Bulk:               2030   2320
2420                     2395   2445
2450                     2390   2485
2490 Stars:             2415   2435   2475
2520 Picture:            300   2550   2570   2580   2705   3040   3060
2585 Hard_output:        425   1830   2605   2615   2890
2610 Gval:              2570
2710 Mix_plot:          2570
3065 Bye:                300
3085                     3075
3095                     3085
3110 En:
```

SUB PROGRAM M2

COMMON VARIABLES:

VARIABLES:
```
 Cl           3130   3150
 Ddqwdt       3115   3205
 Ddtedt       3115   3200
 Delr         3115   3180   3200   3210
 Dhdt         3115   3195
 Dqdzu        3115   3205
 Dqw          3115   3180   3205   3215
 Dqwdt        3115   3215
 Dte          3115   3180   3200   3210
 Dtedt        3115   3210
 Dtedzu       3115   3200
 Dtemp        3185   3200   3210
 Q10          3115   3155   3160   3185
 Q1           3160   3170   3185
 Qliq         3170   3180
 Qs           3165   3180
 Qst          3115   3145   3180
 Qv           3160   3165
 Rh           3160   3165
 T10          3115   3120   3155   3180
 Te           3155   3160
 Thet         3125   3150   3200   3210
 Theta        3115   3185
 Thr          3160   3180
 Tsfc         3115   3130
```

```
Tsky                    3115   3180
Tst                     3115   3135   3180
Tstv                    3115   3140   3180
Tt                      3120   3125   3130   3150
Ust                     3115   3135   3140   3145   3180
We                      3190   3195   3200   3205   3210   3215
We2                     3180   3190
Wq                      3145   3150   3205   3215
Ws                      3115   3195
Wt                      3135   3150
Wte                     3150   3200   3210
Wtv                     3115   3140
Zi                      3115   3120   3125   3160   3180   3185   3200
                        3205   3210   3215
Zlcl                    3115   3160   3180   3185
```

USER DEFINED FUNCTIONS:

SUB PROGRAMS:
```
 Parcel0                3160
 Shrtwv                 3185
 We2                    3180
```

JUMP TARGETS:

FNQvalue

COMMON VARIABLES:

VARIABLES:
```
 Qvb                    3230   3235
 R                      3225   3230
 Tx                     3225   3230
```

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

SUB PROGRAM Frame::

COMMON VARIABLES:

VARIABLES:
```
 A                      3755   3760
 Bb                     3370   3380   3385   3390   3400
 Bbb                    3375   3385   3400
 Cc                     3360   3365   3370   3375   3395   3405
```

Cv	3410	3415	3420	3425	3575	3530	3585
		3590					
D	3525	3530	3535	3540			
Dqdzu	3245	3640					
Dtdzu	3245	3645					
E	3660	3675					
Frame(*)	3245						
Frame_date$	3245	3310					
Frame_loc$	3245	3310					
G(*)	3245	3430	3445	3460	3470	3485	3495
		3625	3630	3640	3645	3755	
Hd$	3735	3790	3795				
Hrg	3615	3625	3630	3640	3645	3755	
I	3620	3640	3645	3655	3665	3675	3630
		3710	3715	3720			
Mhr	3245	3360	3440	3465	3490		
Nrll	3245	3270	3275	3230	3285	3305	3320
		3330	3350	3360	3415	3430	3440
		3460	3465	3485	3490	3615	
P	3655	3660	3675				
Pm	3610	3695	3705	3715	3735	3740	3750
		3930					
Pp(*)	3675	3705	3715	3725	3735	3740	3930
Ppl	3640	3660					
Pp2	3645	3665					
Pr	3605	3610	3615	3765			
Press	3245	3655					
Sbd	3565	3315	3940				
T	3665	3675					
Tday$	3245	3300					
V	3440	3445	3450	3465	3470	3475	3490
		3495	3500				
Zg(*)	3255	3595	3600	3625	3630	3640	3645
		3655	3665	3675	3705	3715	3735
		3740	3930				

USER DEFINED FUNCTIONS:
FNRelhum   3755

SUB PROGRAMS:

JUMP TARGETS:
3510 Profile:
3840   3815
3915 Sfc_duct: 3725

FNRelnum

COMMON VARIABLES:

VARIABLES:

```
 C                         3975   3985
 P                         3980   3985
 Q                         3965   3985
 Relhum                    3985   3990
 T                         3965   3970
 Tl                        3970   3975
```

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

SUB PROGRAM We2

COMMON VARIABLES:

VARIABLES:
```
 A            4085
 Beta         4060   4065   4125   4130   4135   4140
 Dl           4075   4150
 D2           4065   4145   4150   4165   4170   4175
 Delr2        4000   4185
 Dqsdt        4055   4060
 Dqw          4000   4005   4065   4075
 Dte          4000   4005   4065
 Dth          4005   4070
 Dthl         4070   4075
 Emiss        4035   4090   4095
 Epsilon      4020   4060   4075
 Ml           4125   4155
 M2           4135   4155
 M3           4145   4155
 Nl           4130   4155
 N2           4140   4155
 N3           4150   4155
 Qliq         4000   4030
 Qs           4000   4055   4075
 Qst          4000   4110
 Rb           4090   4100   4135   4140   4185
 Rc           4095   4100   4135   4185
 See          4080   4100   4125   4130   4135   4140   4145
              4150   4165   4170   4175
 Sigma        4025   4090   4095
 Tb           4045   4050   4090
 Tbar         4050   4055   4065   4075
 Tc           4040   4095
 Th           4015   4040   4050   4060   4070   4125   4130
 Thl          4000   4015
 Thr          4010   4045   4070
```

Thrl	4000	4010				
Tsfc	4000	4095				
Tsky	4000	4090				
Tst	4000	4105				
Tstv	4000	4115				
Ust	4000	4105	4110	4115		
We2	4000	4155	4160	4165	4170 4175 4180	
Wl	4030	4035				
Wq	4110	4120	4125	4130		
Wth	4105	4120				
Wthe	4120	4125	4130			
Wthv	4115	4125	4130	4170	4175	
Zi	4000	4035	4045	4080		
Zlcl	4000	4035	4040	4080		

USER DEFINED FUNCTIONS:

FNHvi	4085	4125	4130	4135	4140 4145 4150	

SUB PROGRAMS:

JUMP TARGETS:

4185	4160

SUB PROGRAM Parcel0

COMMON VARIABLES:

VARIABLES:

Dqdt	4285	4315					
Dthe	4285	4290	4295				
Gam	4200	4255	4365	4415			
Gamdew	4205	4345					
Lcp	4210	4240	4250	4235			
Ql0	4195	4215					
Ql	4195	4420					
Qq	4215	4385	4435				
Qt	4215	4240	4380	4385	4420		
Qv	4195	4275	4285	4315	4385	4420	
Qvb	4275	4315	4325	4335	4380		
Qx	4435	4440					
Rh	4195	4380	4410				
Sig	4330	4335	4430	4435			
T	4260	4285					
Td	4230	4415	4440				
Tdl0	4230	4345					
Tdo	4255	4260	4305				
Th	4195	4250	4255	4285	4295	4360	4365
	4415						
The	4195	4240	4400				
Thez	4250	4285	4400				

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```
Thr                      4240   4345   4360
Tx                       4260   4305   4325   4365
Z                        4195   4235   4255   4355   4365   4370   4415
Zs                       4195   4345   4350   4355
Zz                       4220   4235   4265   4330   4370   4430
```

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:
```
 4250  Theth:           4405
 4255  Cycle:           4300
 4305  Dqdtcal:         4280
 4325  Qvcal:           4270   4310   4375
 4345                   4245
 4400                   4355
 4420                   4395
 4430  Td_find:         4225   4390
```

SUB PROGRAM Shrtwv

COMMON VARIABLES:

VARIABLES:
```
 Cldthk                  4485   4490   4515   4545
 Delz                    4490   4515   4570
 Dr(*)                   4480   4495   4500   4505   4510   4535
 Dtemp                   4455   4460   4570
 Fbotdif                 4545
 Fbotdir                 4545
 Fheat                   4545   4570
 Ftop                    4545
 I                       4530   4535   4540
 Qlbm                    4455   4470   4475
 Qq                      4475   4515   4520   4525
 Qt                      4455   4515
 Rm                      4525   4535
 Sh                      4515   4545
 Theta                   4455   4460   4465   4545
 Xnd(*)                  4480   4535   4545
 Zb                      4455   4460   4465   4435   4570
 Zc                      4455   4460   4465   4435
```

USER DEFINED FUNCTIONS:

SUB PROGRAMS:
```
 Kahnrad                 4545
```

JUMP TARGETS:
```
```

```
SUB PROGRAM Int779

COMMON VARIABLES:

VARIABLES:
 Ix                        4580    4590    4595    4600    4605    4615    4620
                                   4625    4635    4640    4650
 Nxy                       4580    4590    4620
 Slope                     4580    4635    4640
 X                         4580    4595    4615    4640
 Xarray(*)                 4580    4595    4615    4635    4640
 Y                         4580    4640
 Yarray(*)                 4580    4635    4640

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:
 4595                      4610    4630
 4615                      4595
 4635                      4615
 4655                      4645
 5020                      4600    4620


SUB PROGRAM A52

COMMON VARIABLES:

VARIABLES:
 U                         4665    4690    4695    4700    4705    4710    4715
                                   4720    4725    4730    4735
 Xkv(*)                    4665    4685    4690    4695    4700    4705    4710
                                   4715    4720    4725    4730    4735

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:


SUB PROGRAM A20

COMMON VARIABLES:

VARIABLES:
 A(*)                      4750    4830    4835    4840    4345    4850    4855
```

```
Af(*)                    4750    4765
Ag                       4750    4845    4850    4855
Al                       4750    4820    4840    4855
Be                       4750    4825    4840    4855
D                        4750    4765
D1                       4795    4805    4810    4820    4825
D2                       4800    4805    4810
D3                       4815    4820    4825
Dr(*)                    4750    4765
Fi(*)                    4750    4770
Fo                       4770    4820    4825    4855
Fq                       4775    4785    4790
G                        4765    4775    4780    4800    4820    4825
Iw                       4750    4765    4770
Om                       4765    4785    4790    4795    4800    4820    4825
P                        4750    4810    4830    4835    4845    4850
Qext(*)                  4750    4765
Sa(*)                    4750    4765
Sh                       4750    4765
T                        4750    4765    4785    4845    4850    4855
Tau(*)                   4750    4765
Xk                       4750    4805    4815    4845    4850
Xkv(*)                   4750    4765
Xmu                      4750    4815    4820    4825    4855
Xnd(*)                   4750    4765
```

USER DEFINED FUNCTIONS:

SUB PROGRAMS:
```
 A28                     4765
```

JUMP TARGETS:

SUB PROGRAM A30

COMMON VARIABLES:

VARIABLES:
```
 Al                      4870    4890    4915
 Be                      4870    4895    4920
 Fbotdif                 4870    4935
 Fbotdir                 4870    4940
 Fd                      4900    4905    4910    4930    4940
 Fi(*)                   4870    4900
 Fl                      4870    4925    4930
 Ftop                    4870    4905
 Ftopd                   4870    4910
 I0                      4890    4905    4915    4935
 I1                      4895    4905    4920    4925    4935
 Iw                      4870    4900
```

```
P                         4870   4895   4920
Γ                         4870   4915   4920   4930   4940
T0                        4885   4890   4895
X(*)                      4870   4890   4895   4915   4920
Xk                        4870   4890   4895   4915   4920
Xmu                       4870   4890   4895   4900   4915   4920   4930
                          4940
```

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

SUB PROGRAM A28

COMMON VARIABLES:

```
VARIABLES:
 Af(*)                    4955   5010
 D                        4955   4980   5020
 Dr(*)                    4955   4980
 G                        4955   4970   5010
 Iw                       4955   4980   5005   5010   5025
 J                        4975   4980   4985   4990   5000   5005   5010
                          5015
 Om                       4955   4970   5005   5025
 Qext(*)                  4955   4980
 Sa(*)                    4955   5005
 Sh                       4955   5020
 T                        4955   4995   5025
 Tau(*)                   4955   4980   4985   5005   5010
 Ts                       4970   4985   4995   5005   5010
 Vp                       5020   5025
 Xkv(*)                   4955   5025
 Xnd(*)                   4955   4980
```

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

SUB PROGRAM A100

COMMON VARIABLES:

```
VARIABLES:
 Af(*)                    5040   5150
```

Dr(*)	5040	5090	5125				
I	5120	5125	5135	5140	5145	5150	5155
Ix9	5105	5110	5115	5135	5140	5145	5150
		5160					
Qext(*)	5040	5135	5140				
Qsca	5135	5140					
R0	5130	5150					
R2	5125	5130					
Sa(*)	5040	5140	5145				
Xk9(*)	5055	5095					
X10	5110	5130					
X19(*)	5055	5090	5110				
Xn0	5115	5130					
Xn9(*)	5055	5090	5115				

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:
5060   5085

SUB PROGRAM Kannrad

COMMON VARIABLES:

VARIABLES:
A(*)	5190	5330	5350	5375	5380	5385	5395
	5410	5425	5435	5465	5470	5490	
Af(*)	5195	5310	5330				
Ag	5285	5290	5330				
Al	5330	5500					
Alam(*)	5200	5235	5275				
Be	5330	5500					
Cldthk	5175	5240	5295				
D	5305	5330	5515				
Dd	5350	5355	5395	5410	5425	5435	
Delz	5295	5305					
Dr(*)	5200	5310	5330				
Fbotdif	5175	5245	5500	5535			
Fbotdir	5175	5245	5500	5530			
Fheat	5175	5515					
Fi(*)	5205	5235	5275	5330	5500		
Fl	5300	5500	5515				
Ftop	5245	5500	5515	5525			
Ftopd	5245	5500	5520				
Ftopdir	5245						
I	5270	5275	5280	5485	5490	5495	
Il	5345	5360	5365	5380	5385		
Ibi	5405	5410	5415				

```
Iinc0                  5175  5520  5525
Itest                  5175  5250
Iw                     5325  5330  5500  5505
Iwi                    5370  5375  5380  5385  5390
J                      5420  5425  5435  5445  5460  5465  5470
                       5475
K                      5430  5435  5440  5455  5460  5465  5470
                       5480
L                      5340  5345  5350  5375  5380  5395  5410
                       5420  5425  5435  5450
P                      5330  5500
Qext(*)                5195  5310  5330
R(*)                   5190  5375  5385
Sa(*)                  5195  5310  5330
Secmu                  5265  5275
Sh                     5175  5240  5330
T                      5330  5500
Tau(*)                 5200  5330
Theta                  5175  5250  5255
U                      5240  5315
X(*)                   5190  5490  5500
Xk                     5330  5500
Xkv(*)                 5205  5315  5330
Xmu                    5255  5260  5265  5290  5330  5500
Xnd(*)                 5175  5330
```

USER DEFINED FUNCTIONS:

SUB PROGRAMS:
```
A100                   5310
A20                    5330
A30                    5500
A52                    5315
```

JUMP TARGETS:
```
5215                   5230
5285                   5260
5355                   5400
5405                   5355
5545                   5365
```

SUB PROGRAM Sky2

COMMON VARIABLES:

VARIABLES:
```
Emit(*)                5580  5700  5725  5735  5760  5765  5795
Es                     5725  5760
Ftop                   5555  5775  5790  5795
Gad                    5605  5695  5730  5750  5785
```

```
I                       5705  5715  5720  5730  5745
Icloud                  5655  5715  5770  5785
Ie                      5725  5760
Ii                      5605  5700  5710  5725  5735  5760  5765
                        5795
Itop                    5670  5675  5680  5685  5695  5705
Nemis                   5610  5725  5760
Nsnd                    5555  5655  5660  5665  5670  5705  5750
                        5755  5770
Pot_temp(*)             5555  5595
Qtsnd(*)                5580  5590  5720  5755
Rho0                    5605  5720  5755
S                       5605  5735  5765  5795
Sig                     5605  5735  5765  5790  5795
Spec_hum(*)             5555  5590
Temis(*)                5580  5600  5725  5760
Thrsnd(*)               5580  5595  5695  5730  5750  5785
Tsky                    5555  5795
Tt                      5730  5735  5740  5750  5765  5735  5790
Tts                     5695  5735  5740
Tu(*)                   5580  5600  5725  5760
U                       5605  5720  5725  5755  5760
Zi                      5555  5675
Zscale                  5605  5720  5755
Zsnd(*)                 5555  5675  5695  5720  5730  5750  5755
                        5785
```

USER DEFINED FUNCTIONS:

SUB PROGRAMS:
```
Int779                  5725  5760
```

JUMP TARGETS:
```
5560                    5585
5685                    5675
5785                    5715
5795                    5780
```

SUB PROGRAM Zenith

COMMON VARIABLES:

VARIABLES:
```
Decl                    5835  5840
H                       5830  5835
Hr                      5820  5840
Julday                  5810  5830
Lat                     5810  5825
Latr                    5825  5840
Theta                   5810  5840  5845
```

Time   5810   5320

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

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